UNIVERSITY GEOLOGICAL SURVEY
of
KANSAS

GREAT SPIRIT SPRING. Waconda, Mitchell County.

See pages 197–205.

THE UNIVERSITY

GEOLOGICAL SURVEY

OF

KANSAS.

CONDUCTED UNDER THE AUTHORITY OF THE BOARD OF REGENTS OF THE UNIVERSITY OF KANSAS, AS AUTHORIZED BY SPECIAL LEGISLATION.

VOL. VII.

SPECIAL REPORT ON MINERAL WATERS.

BY

E. H. S. BAILEY,

ASSISTED BY

E. B. KNERR, W. R. CRANE, AND D. F. McFARLAND.

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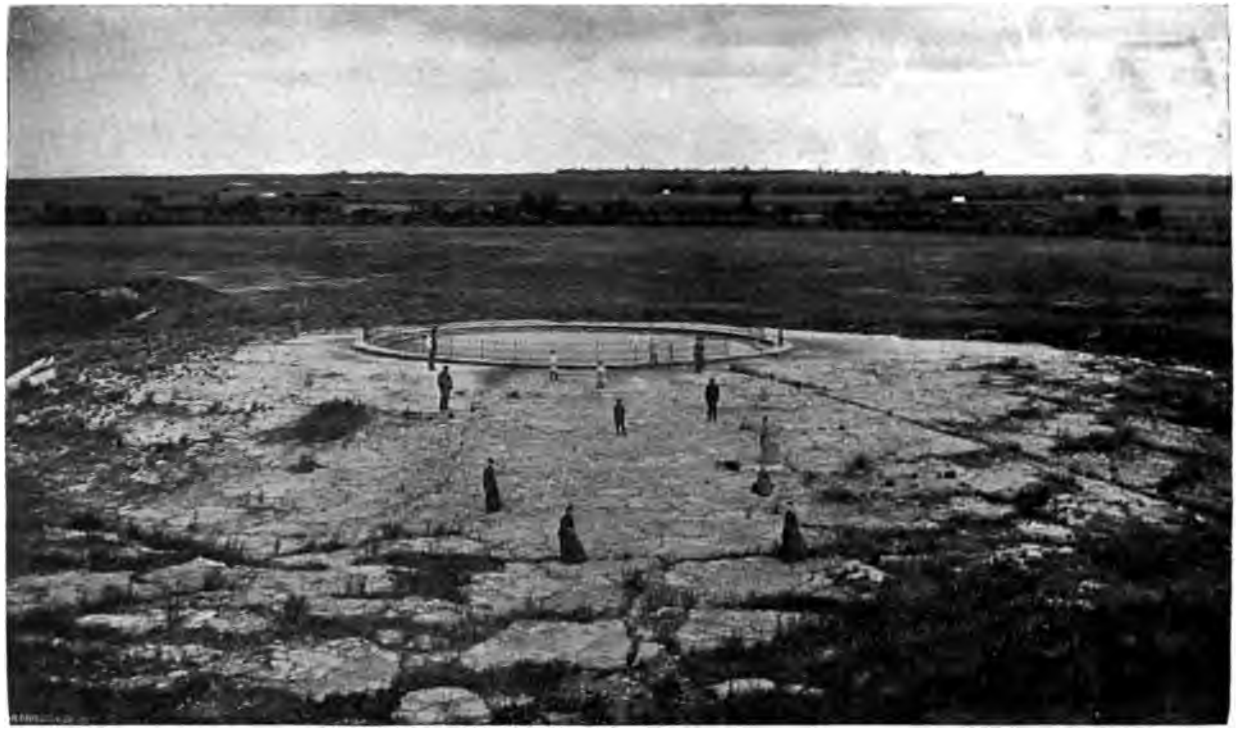

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FOR VOLUME VII.

E. H. S. BAILEY, Chemist.
E. B. KNERR, Assistant Chemist.
D. F. McFARLAND, Assistant Chemist.
W. R. CRANE, Mining Engineer.

Acting Chancellor W. C. Spangler,
Ex officio Director of the University Geological Survey:

SIR—I have the honor to submit to you herewith a special report on the Mineral Waters of Kansas, prepared by the Department of Chemistry of the University. This report will constitute Volume VII of the University Geological Survey of Kansas. I desire, at the same, to express to you, and through you to the Board of Regents of the University, my hearty appreciation of the many facilities afforded this Department, without which the carrying on of this research would have been impossible.

Respectfully,
E. H. S. BAILEY.

DEPARTMENT OF CHEMISTRY,
UNIVERSITY OF KANSAS, April 10, 1902.

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PART II.

MINERAL WATERS OF KANSAS, ARRANGED AND CLASSIFIED, WITH ANALYSES.

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PREFACE.

In the course of an experience of many years in a chemical laboratory, the author has had occasion to examine, for one purpose or another, a large number of waters. Questions in regard to the sanitary quality of a water, its adaptability for public city supply, its availability as a boiler water, whether it has valuable medicinal qualities, so that it can be used for drinking or bathing purposes, or can be shipped as a commercial water, are constantly coming up.

By keeping a careful record of the examinations made through a series of years in Kansas, the author has been able to draw upon much valuable data in the preparation of these pages. As the state has been in the process of development, and through one or two "boom periods," everything that appeared to be of prospective value has been investigated. Many prospect "borings" have been made, especially since gas and oil have been found so abundantly in the eastern part of the state. By popular subscription, often, wells have been sunk, with the avowed purpose of "finding out what was below us." Sometimes these have been "dry holes"; but often, if they yielded nothing else, they have produced a mineral water, which, though not always immediately of commercial value, has proved of scientific interest.

The chemical analyses thus made have, many of them, been qualitative only, but they have been sufficient to show whether the waters probably possessed valuable therapeutic qualities. If they seemed to be of value, a more complete quantitative analysis was usually made. Without paying much attention to the marvelous cures "said to have been accomplished" by these waters, it was thus possible to obtain some facts as to their probable value. Some of the springs and wells discussed in the following pages are only ordinary, wholesome waters, though they may have acquired a local reputation in the treatment of

disease. From the analysis, however, it is not difficult for the medical practitioner to ascertain whether a given water will probably be useful in a certain specific case.

Although this report contains analyses made by the author as early as 1883, and from that time to the present, yet it is only since 1896 that any special attention has been directed to the systematic analysis of the mineral waters of the state. The more important localities have been personally visited, and samples of water have been secured, and, at the same time, special observations have been made upon temperature, flow, situation, dissolved gases, etc., which could be made only at the original source of the water.

There are included in the list of analyses, however, quite a large number of waters that have been analyzed at the State Agricultural College, at Manhattan, by Prof. G. H. Failyer and his assistants, reports of which have been published in various scientific periodicals. Other analyses, as reported by chemists outside the state, are also quoted. The department is also indebted to Dr. E. B. Knerr, of Midland College, Atchison, for his constant interest in the work, and for furnishing analyses of the waters in the vicinity of Baxter Springs, Atchison, and from Brown county.

Several of the faculty of the Chemistry Department, especially Prof. E. C. Franklin, Prof. H. P. Cady, Mr. D. F. McFarland, and some advanced students of the University, have contributed not a little to the facts here recorded. The analyses are, as far as possible, credited to the proper persons.

It has been the object of the department to thus collect and preserve in a permanent form, for the benefit of the citizens of the state, as much reliable material as possible on the mineral waters. It has not been thought to be advisable to include in this volume the very closely related subject of the potable waters of the state, city supplies, and those used for domestic supply; so the investigation of the rivers and streams has been left for a later and more extended research.

It is not possible in a limited time to describe and study all the so-called mineral waters of the state, and it is quite probable

that some wells and springs having considerable reputation have been omitted; but if this proves to be the case, it is because diligent inquiry has failed to find them.

Most of the plates are made from photographs by the author, the object being to show what improvements have already been made and what natural advantages the localities offer. The plates showing geological sections and maps illustrative of geological position, as well as the text of two important chapters, were prepared by Dr. W. R. Crane, of the University Faculty.

INTRODUCTION.

It is evident that a geological survey of a section is not complete unless considerable attention is paid to the mineral waters, for they hold in solution the soluble constituents of the soil and the rocks, and their composition depends on the constitution of the superficial or underground strata.

The chief writers on this subject in the United States, aside from those who write in government reports, are Dr. John Smith, the author of "Curiosities of Common Water," American reprint, who wrote in 1725. Dr. John Smith published a book on "Baths and Mineral Waters," 1831, and also wrote "Mineral and Thermal Springs of the United States and Canada," 1873. Dr. J. J. Moorman wrote "Mineral Springs of North America in 1873." Dr. Geo. E. Walton wrote "Mineral Springs" of United States and Canada," third edition, 1883. A very complete compilation was made by a committee of the American Medical Association in 1880. In 1885 Doctor Bell published "Climatology and Mineral Waters of the United States."

In Bulletin No. 32, United States Geological Survey, 1886, Doctor Peale mentioned 2822 mineral-spring localities and 8843 individual springs, 634 of which were utilized as resorts, and 223 as sources of commercial mineral water. Besides the above, there is a large amount of valuable material in the reports of the geological surveys of the various states and of the United States. The most recent work published in this country is "Mineral Waters of the United States, and their Therapeutic Uses," by Dr. James K. Crook, Philadelphia, 1899. An interesting historical bibliography on mineral waters appeared in the report of the mineral waters of Missouri, by Doctor Schweitzer, pages 236–244. A partial bibliography of mineral waters is given in the latter part of this book.

According to the report of the U. S. Geological Survey on "The Production of Mineral Waters," for 1900, by A. C. Peale,

there are in the United States from 8000 to 10,000 mineral springs, and of these about 500 report sales of waters. The average price charged per gallon was 12.5 cents; the total number of gallons sold was 45,276,995, having a value of $5,791,805. So it may be seen that this is no inconsiderable industry. Wisconsin reports the largest amount of water sold, and this state is followed by Texas, Massachusetts, and New York. In Kansas only six springs are reported for that year, with a total sale of but 52,475 gallons.

The amount of mineral water, both natural and artificial, that has been imported has steadily increased, from about one and one-half million gallons in 1884 to nearly two and one-half millions in 1900.

That mineral springs add to the wealth of a locality is readily conceded. This is the case because they become places of resort, and expensive hotels and bathing establishments are erected; also on account of the business of bottling the waters for shipment; and, in a few cases, on account of the manufacture of mineral salts for physicians' use, by the evaporation of the waters.

Says a well-known authority:[1] "It has long been known that mineral springs are numerous in the United States, among which all classes of waters may be found. That the majority are unimproved is due mainly to the comparative newness of the country, and the consequent sparseness of the poplation—especially in the territories and the extreme Western states—and also to the fact that the springs have not as yet been made the subjects of careful and complete investigation as is the case of so many foreign springs. Many of the springs allowed to run to waste would, in most European countries, be of considerable value."

1. A Treatise on Beverages, by Chas. H. Sulz, p. 507.

PART I.

GENERAL DISCUSSION OF MINERAL WATERS.

CHAPTER I.

THE SOURCES OF MINERAL WATERS.

SOME DEFINITIONS.

1. Herpin defines mineral waters as all waters which, by the nature of their principles or by their therapeutic action, differ from drinkable waters.

2. Ossian Henry, sr., says: "Mineral waters are those waters which, coming from the bosom of the earth at variable depths, bring with them substances which may have upon the animal economy a medical action capable of giving rise to effects often very salutary in the different diseases affecting humanity."

3. M. Durian-Fardel, speaking of mineral waters, says they are "natural waters which are employed in therapeutics because of their chemical composition or their temperature."

4. A mineral water, in the medical acceptation of the term, is one which by virtue of its ingredients, whether mineral, organic, or gaseous, or the principle of heat, is especially applicable to the treatment of disease.[2]

5. Mineral waters are those natural waters which contain an excess of some ordinary ingredients or a small quantity of some rare ingredients, and which on this account are used as remedial agents.

As an indication of what the United States government is doing in gathering statistics of the production of mineral waters, and to show how much the term "mineral waters" covers, the following, by A. C. Peale, of the United States Geological Survey, from the circular just sent to all the mineral springs proprietors in the United States, is quoted:

"Our reports do not restrict the term 'mineral waters' to medicinal waters, but includes all spring waters put on the market, whether they are utilized as

2. Mineral Springs of United States and Canada, Walton, page 14.

drinking or table waters, or for medicinal purposes, or used in any other way. If the water comes from a spring and is put on sale—in bottles, jugs, barrels, or any other way—it is entitled to a place in our reports. If, therefore, you sell a spring water, please send us an estimate of your sales for 1901, no matter what the amount—large or small. The information received is regarded as confidential, the figures, as published, being included in the totals by states, as will be seen on reference to the report sent you herewith."

In studying these waters, there is also a class of waters sometimes called neutral, like the Poland spring, in Maine, which are simply very pure, and which have a beneficial effect upon the system when taken in large quantities by reason of their very purity. These contain no special mineral constituents, but sometimes, on account of the heat at which they are discharged from the earth, or sometimes simply because of their very purity, they have found favor as remedial agents.

ORIGIN OF MINERAL WATERS.

It is no doubt true that the study of the origin of mineral springs belongs properly to the science of geology; yet as the geologist must refer ultimately to the chemist in explaining this subject, it is proper to consider it from this standpoint also. M. Garrigau divides the geological distribution as follows:

1. Warm waters are found in the oldest rocks (granites).
2. Bicarbonate and gaseous waters in the midst of volcanic rocks.
3. Ferruginous waters should have their origin in the strata of transition.
4. Simple saline waters, obtained in the secondary strata or at their limits.

Our best received theory in regard to the earlier history of water is, that while this globe was hot and surrounded by vapors there was mingled with the vapor of water that of other substances which at the present time are solids. This condensing vapor would carry with it to the earth greater or less quantities of other elements condensed, and these no doubt formed a basis for the oceans as they now exist. As the sea has given up much of its mineral matter to the earlier forms of life—that is, as such immense quantities of fossil remains containing sub-

stances that originally were present in the waters are found—it is possible that the ocean has changed much in composition.[3]

It is easily understood, however, that the great contributions to the solid matter of the sea have come from the mineral matter dissolved from the streams that are continually carrying their burden to the ocean. These streams not only carry immense quantities of suspended matter which is building the great deltas in front of the mouths of the large rivers, but they have carried the soluble matter of the rocks and soils over which they have passed. On this theory, too, one should expect to find all the elements that are found on land in varying proportions in the sea water. This is practically true, for even such an insoluble substance as gold is present in an appreciable quantity. Forchhammer[3] mentions twenty-seven of the elements as found in the sea water, and to these, others such as arsenic, lithium, cæsium, rubidium and gold should be added.

Dittmar,[4] in his report on the waters collected in the "Challenger" expedition, gives the following as the average composition of sea water:

Uncombined.		*Combined.*	
Chlorin (Cl)	55.292	Sodium chlorid (NaCl)	77.758
Bromin (Br)	.188	Magnesium chlorid ($MgCl_2$)	10.878
Sulfuric anhydrid (SO_3)	6.410	Magnesium sulfate ($MgSO_4$)	4.737
Carbonic anhydrid (CO_2)	.152	Calcium sulfate ($CaSO_4$)	3.600
Calcium oxid (CaO)	1.676	Potassium sulfate (K_2SO_4)	2.465
Magnesium oxid (MgO)	6.209	Magnesium bromid ($MgBr_2$)	.217
Potassium oxid (K_2O)	1.332	Calcium bicarbonate ($CaH_2(CO_3)_2$)	.345
Sodium oxid (Na_2O)	41.234	Total salts	100.00
Less oxygen equivalent	12.493		
Total salts	100.00		

Other authors state the saline matter in the ocean to be from 3.47 to 3.51 per cent., and note the fact that inland seas would not be so strong where they received large accessions of fresh water from rivers, while in some situations bays and shallow seas might become more concentrated from excessive evaporation of water.

3. Philos. Trans. K. C. I. V., p. 205.
4. Report of the Voyage of the "Challenger," 1884.

As sea water contains calcium carbonate, which is appreciably alkaline, and as it is in contact with the great oceans of atmosphere above, it naturally absorbs the gases contained therein. Dittmar[5] found that a liter of sea water would take up, at zero degrees C., 15.60 cc. of nitrogen and 8.18 cc. of oxygen, while at thirty degrees the proportions were 8.36 cc. of oxygen and 4.17 cc. of nitrogen. Buchanan[6] found the amount of carbon dioxid in surface-waters to be at twenty to twenty-five degrees C. from .0466 grams per liter to .0268. The carbon dioxid is mostly united with sodium, although a small amount is united with calcium.

RAIN WATER.

The rain, which has been evaporated from the surface of the earth, which floats over our heads in clouds, is condensed and again waters the earth, is the original material from which mineral water is made. As it answers as a vehicle for dissolving and transferring the mineral substances, its characteristics and composition should be first discussed. As the rain falls through the air it not only takes up the dust and floating particles, which in cities and manufacturing districts are liable to be abundant, but it absorbs certain gases. The per cent. of these gases, by volume, according to Baumert,[7] is, of nitrogen, 64.47; of oxygen, 33.76; of carbon dioxid, 1.77. We find normally about three parts of carbon dioxid in 10,000 parts of the atmosphere, and the carbon-dioxid gas being very soluble in water, the rain as it descends is found to contain fifty times as much as the same volume of air would contain.

The newly discovered gases argon and helium are probably also present in rain water. Nitric or nitrous acid, uniting with ammonia, will be found in considerable quantity, and in the vicinity of towns and manufacturing centers hydrogen sulfid and sulfuric acid, and even such a solid substance as sodium chlorid (common salt) is liable to be present in rain water, especially in the vicinity of the ocean. Interesting experiments

5. Report of the Voyage of the "Challenger," 1884.
6. Proc. R. S. vol. [illegible]
7. Ann. Chem. Pharm. LXXX, VIII [illegible]

on this point have been made under the direction of boards of health, both in Europe and this country. In Massachusetts, for instance, a study was made of the well waters with respect especially to their chlorin contents, and it was found that the line of equal chlorin content was quite closely parallel to the coast-line, and as the wells were farther away from the coast the amount of salt in the water diminished quite regularly in proportion to that distance. The fine particles of salt are carried in the air, especially during storms, and the rain washes this salt into the soil, so that its presence may be detected in the well waters. At Land's End,[8] in Cornwall, it was found that rain contained 3.59 parts of salt per 10,000 parts of water, while the mean proportion in England is only .022 per 10,000.

Though we may have what may be called distilled water in the clouds, it is evident that by the time it has reached the earth this water has taken up many impurities. For instance, J. Pieirre estimated that in France each hectare of land received annually from the rain alone 78.5 kilograms of mineral matter which had been washed out of the atmosphere.

The rain water, having reached the surface of the earth, begins to do chemical work on the substances which come in contact with it, and these things which the rain water has absorbed, especially oxygen, carbon dioxid, and organic matter, assist greatly in producing these chemical changes. According to Geikie,[9] these changes may be best considered as:

1. Oxidation, from the oxygen in the water. Common examples of this are the changing of the sulfids to sulfates, as the change which takes place in ordinary pyrite by which it becomes copperas and later limonite, with the setting free of sulfuric acid. In all zinc and lead regions, as in the southeastern part of Kansas, localities are found where the blend (zinc sulfid) has been changed partially to zinc sulfate, and even galena (lead sulfid) to lead sulfate, by oxidation.

2. Deoxidation, as when organic and vegetable matter *reduces* sulfates to sulfids, which, in contact with water and car-

8. Text-book of Geology, Geikie, page 341.
9. Text-book of Geology, Geikie, pp. 343-345.

bon dioxid, give off hydrogen sulfid. This may be considered a common source of hydrogen sulfid in so-called sulfur waters.

3. Solution, as in the case of salt and to some extent gypsum. This solution is frequently very much aided by the presence of carbon-dioxid gas in the water. Gypsum, for instance, dissolves in the proportion of one part per 1000 in water saturated with carbon dioxid; but it dissolves in the proportion of about one part per 400 in ordinary water.

4. The formation of carbonates, as in the case of complex silicates like feldspar, which absorbs the carbon dioxid from the rain water and forms carbonates with the liberation of silica. By the process of disintegration, clay, a hydrous aluminum compound, is formed, while nearly all the other elements of feldspar are dissolved and carried away by the water.

5. Hydration, as in the case of minerals like anhydrite, which by absorbing water leaves gypsum, and some iron minerals, which after oxidation take up the water.

SEA WATER.

As without doubt the original water upon the earth's surface was sea water, in the study of mineral waters it is appropriate to study ocean water first. M. Antoine D. Saporta[10] says that the taste of sea water is due to the presence of salt, and the peculiar bitter taste to the magnesium salts in the solution. It was once held that the bitter taste was due to bitumen, and, indeed, artificial sea water was made in the time of Louis XIV, and bitumen in small quantities was actually introduced to imitate the taste, but M. Lavoisier, more than 100 years ago, distilled sea water and proved that there was no bitumen in it, and that the bitter taste was due rather to magnesium salts. The ocean may be considered as a great inexhaustible mineral spring. The ingenuity of man has been taxed many times to obtain pure drinkable water from the brine of the ocean, and numerous ingenious devices have been brought forward for this purpose. Practically, however, the only efficient method is simply the boiling of the water and condensing the steam.

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10. Pop. Sci. Mo. XXVI, pp. 529-541; trans. from Revue des Deux Monde.

"It is generally known that a strong dose of sea water acts as an emetic; in larger proportions it is a purgative and diuretic. Dioscroides advised diluting it with honey, which might perhaps produce an effective medicine, but certainly not a savory one. At the beginning of this century it was diluted with wine, but such a mixture would hardly be better than the previous one. It was prescribed in Spain against yellow fever, and in England against worms; in the former case as an emetic, and in the second case milk was added to it, so that the child could drink it without aversion."

On concentrating, sea water deposits calcium carbonate, calcium sulfate, sodium chlorid, then the magnesium salts, while bromin and iodin compounds accumulate in the mother-liquors and can be finally obtained from this source. It is a well-known fact that brine springs, especially some found in Ohio and West Virginia, contain sufficient quantity of bromin so that the mother-liquor, after the separation of salt, is used for the manufacture of bromin. Iodin was discovered in 1812 by Courtois in sea water. Moloquette discovered copper, lead, sulfur and iron in seaweed, and they were afterwards found in sea water. Some compounds of iodin and bromin, especially the former, seem to be concentrated in animal tissue, as in the familiar case of iodin in cod-liver oil. M. Dieulafait showed that the Dead Sea was not originally a part of the Red Sea, as he found neither iodin, lithium nor sulfur in the Dead Sea and found them in the Arabian gulf.

WHAT IS A MINERAL WATER?

"By their very characteristics,"[11] says Mr. Kellar, "mineral waters yield to a rigorous method of classification with great difficulty. These are complex compounds, or rather mixtures of variable composition. These contain very many substances in solution in greater or less proportion of all the soluble elements of the regions through which they circulate or which they traverse before gushing from the surface of the soil. The multitude of these elements, the chemical analysis of which has not al-

11. A Sketch of the Natural History of Mineral Waters, Frederick Maurin, Sanitarian, vol. 33, pp. 208-209.

ways revealed their mode of composition, renders the rational classification of mineral waters very difficult and very complicated, and the necessity of keeping account of their action on the economy and of their medicinal role, which often seems due to certain substances found there in very small quantity, tends still more to increase the difficulty."

THE CHANGES THAT MINERAL WATERS MAY UNDERGO.

The question may properly be asked, Do mineral waters change their composition? Usually they do not; this may be shown by a comparison of the analysis of a Saratoga water made by Doctor Steel and one of the same water made by Doctor Chandler thirty-nine years later, and these two practically agreed. In the case of the Great Spirit spring, or Wacanda No. 1, the analysis made twenty-one years ago agrees essentially with the analysis made in 1901.

There is an interesting case of a water in Switzerland in which at one time it was reported that iodin was found, and later it could not be found. A more complete investigation showed that in reality the amount of iodin varied from day to day, from none at all, sometimes, to a maximum of 2.25 parts per 10,000 of water.

"The following changes may take place in the composition of water," says Professor Wiln:[12]

"1. Periodic variation, dependent on the mineral water being more or less mixed with superficial sheets of water.

"2. Progressive or secondary, dependent on the rocks washed by the waters, which may be different on account of storms in different places or being more or less diluted.

"3. The action of sunlight may change the composition of the water.

"4. By exposure to the air, which allows the pressure to change and which at the same time allows oxygen to come in contact with the water, many changes may be brought about. It is a well known fact that the mineral matter is often deposited

12. A Sketch of the Natural History of Mineral Waters, Frederick Maurin, Sanitarian, vol. 33, p. 207.

in large quantities from spring water which is allowed to stand in an open vessel.

"5. A difference in temperature may change the composition, as substances held in solution at one temperature may not be soluble at another temperature."

GASES IN MINERAL WATERS.

Oxygen may unite with the constitutents of the water and change the composition, as may also carbon dioxid and certain sulfur compounds. This is not true, however, of nitrogen, as it is so inert that it does not easily unite with the ordinary substances present in the water. By the intervention of bacterial life, and as in the roots of certain plants like clover and alfalfa, the nitrogen of the air is "fixed" so that it can be assimilated, so the influence of plants on the composition of cultivated soil is too important to be ignored.

Nitrogen, Argon, and Helium.

It is an interesting fact that at one time a certain physiological action was attached to mineral waters, and some authorities, especially Spanish physicians, introduced a new class of mineral waters, namely "azoades," or nitrogenous waters. It is quite probable, however, that what was frequently called nitrogen in mineral waters may have been largely helium and argon, as these new elements have been discovered in mineral waters recently. Dr. C. H. Bouckard[13] has found helium and in some cases argon in the mineral waters of the French slope of the Pyrenees. He was led to this investigation by noticing that on the Spanish slope of the Pyrenees certain so-called nitrogenous waters had been discovered. Ramsey[14] has found argon in several mineral springs. Rayleigh[15] found helium in the proportion of 1.24 parts per 1000 in some of the Bath springs. It is by no means proven, however, that in some cases these gases may not have come directly from the air, having been dissolved in the rain water. It is not proven that the nitrogen in the water had a remedial action, any more than it has been proven

13. Comptes Rendus, CXXI, p. 392.
14. Chem. News, vol. 72, p. 95.
15. Chem. News, vol. 73, p. 247.

CHAPTER I.

THE SOURCES OF MINERAL WATERS.

SOME DEFINITIONS.

1. Herpin defines mineral waters as all waters which, by the nature of their principles or by their therapeutic action, differ from drinkable waters.

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2. Mineral Springs of United States and Canada, Walton, page 14.

M. Dieulafait believes these hypotheses are wholly gratuitous, and that "the salts held in solution in the waters of the seas, the salts existing in solid masses in the strata of our globe and those which furnish the mineral constituents of saline waters have a common origin, and that this origin is exterior to the first strata that were formed in the consolidation of the earth."

According to the nebular hypothesis, when the temperature of the mass outside the cooling globe was from 2000 to 2500 degrees C., then chlorin, sulfur, as well as hydrogen and oxygen, would not be united, as all bodies would be dissociated at this high temperature. As the mass cooled, only certain bodies could be formed, and another set of substances would be formed at another temperature. Thus sodium chlorid would have been condensed at a high temperature, but magnesium chlorid could not have been formed till the temperature was much lower; in fact, nearly as low as that of boiling water, as it is readily dissociated at that temperature. Metals combined with sulfur and chlorin; that is, those metals existing on the earliest crust of the earth, such as lithium, potassium, sodium, magnesium, and calcium, and those happened to be the chief constituents of sea water. It seems to be well established from the earliest evidence of life that is found that the earlier seas did not differ materially in their composition, though they differed in a few constituents, from the ocean as it is at the present time. The simplest way of explaining the origin of these saline formations, then, would be to assume that they were the result of the evaporation of saline lakes accidently isolated from the ocean.

Experiments on saline waters have proven that the following deposits would take place upon the spontaneous evaporation of the water:

	Precipitate.
Till 80 per cent. of original volume is evaporated...	$CaCO_3$, $MgCO_3$, Fe $(OH)_3$.
" 8 " more is evaporated................	Gypsum ($CaSO_4+2H_2O$).
" 2 " " "	No precipitation.
" 5 " " "	Sodium chlorid (NaCl).
" 2 " " "	$NaCl+MgSO_4$.
" 1 " " "	Carnellite (KCl, $MgCl_2$).
Remaining 2 per cent. mostly......................	Magnesium chlorid ($MgCl_2$).

In consequence of this order of deposition, we should expect to find these minerals in the reversed order as we dig down into a deposit. The higher salts in the series will be less abundant and less likely to occur. If one of the upper groups is met with we should expect to find the other groups below it. It is remarkable that the strata of the Stassfurt (Prussia) beds show the deposition in the order named, and above the magnesium chlorid is a deposit of boric acid with the magnesium. A study of the ultimate mother-liquor of the water of the salt marshes of the south of France also shows considerable boric acid to be present.

In the Rhone delta, where there is communication between the sea and an inland lake, and where the loss of water by evaporation is made up by more water from the sea, it is noticed that it continues to deposit gypsum at the present time. Another good illustration of the way in which deposition is going on is seen in the Gulf of Karabogaz, on the east side of the Caspian sea, and communicating with it by means of a shallow channel. As there is constant and rapid evaporation in the gulf and no fresh water is coming in, but there is a constant inflow of water from the sea, the result is a continuous and increasing deposit of gypsum. If the supply of water is at any time shut off suddenly we shall have a deposit of a series of salts noted above.

If such is the true theory of the origin of the saline deposits, the saline waters which are so common in many localities, and are especially common in this western Mississippi basin, are the result of the evaporation of the waters originally constituting the primeval ocean.

THE INFLUENCE OF HEATED WATER.

Too much value can with difficulty be given to the influence of water, especially of hot water, in the formation of the crust of the earth. We know that under pressure water will penetrate into rocks that have all the appearance of being solid. The artificial coloring of agates by the use of dyes is a good illustration of what is frequently done in the application of this

principle. The higher the temperature of the water the more rapidly the liquid will flow through the interstices in the rocks, and of course the greater will be the solvent action. It is a familiar fact that the minute cavities of rocks and crystals often contain concentrated solutions of the material of which the rock is composed. There is, in fact, a mother-liquor left in the crystal after it has been formed. As these crystals disintegrate this mother-liquor escapes and adds its mite of mineral salts to the water that flows over the rocks.

Many experiments have been made on the solvent action of liquids upon rocks at a high temperature under pressure. Ordinary glass is a silicate which in its composition suggests that of some of the rocks on the surface of the earth. Every chemist is aware of the action of ordinary chemicals on glass, and knows that in accurate analyses he cannot neglect the action even of boiling distilled water upon it. When water is used as a solvent for chemicals, especially for those which are alkaline in character, it becomes a still better solvent for glass. On this account we use platinum vessels in chemical analyses where great accuracy is required.

THERMAL OR WARM SPRINGS.

The high temperature of some waters as they issue from the earth is ascribed to several causes. Some argue that it is on account of the interior heat of the earth, as it has been noticed in some borings that there was a uniform increase in temperature as the drill descended. This is far from uniform in different localities, however, possibly on account of the varying thickness of the crust of the earth.

Others suppose that chemical action causes the heat of some waters. It is true that oxidation, of sulfur compounds especially, does cause heat, and this and similar reactions may have warmed the water in some localities.

It has been noticed furthermore that more thermal springs are found in volcanic districts or where there are evidences of former volcanic action than elsewhere. Thus, in the United States there are hardly any warm springs in the Northeastern states, but in the main body of the Appalachian chain, from

Virginia south they are numerous; there is a hot-spring area in Arkansas, in the vicinity of the Ozark uplift; and finally all through the Rocky Mountain region. The more the rocks have been displaced by disturbances, the greater the opportunity for these subterranean waters to escape.

As there are all degrees of temperature in waters, we must fix an arbitrary point, say seventy degrees F., and say that any water having a temperature higher than this is to be classed as "thermal."

It may be of interest to note the temperature of a few important springs and wells, both American and foreign, first calling attention to some of the deep wells of southeastern Kansas that yield warm water.

	Degrees, Fahr.
Cherokee city well	71.5
Columbus city well	75.2
Girard city well	75
Sweet Springs, West Virginia	74
Healing Springs, Bath county, Virginia	85
Hot Springs, Bath county, Virginia	98–106
Buncombe county, North Carolina	81–104
Merriwether county, Georgia	95
Warm Springs, French Broad, Tennessee	95
Washita (Hot Springs), Arkansas	140–156
Calistoga Hot Springs, California	100–195
San Bernardino Hot Springs, California	108–172
Skagg's Hot Springs, California	128
Great Salt Lake, Hot Chalybeate, Utah	132–136
Hot Springs, Idaho	164
Las Vegas, New Mexico, Hot Springs	110–140
Hot Springs, Pyramid Lake, Nevada	206–208
Sulfur Springs, Aix-les-Bains, France	108
Kaiserquelle, Aix-la-Chapelle, Reinisch Prussia	131
Hauptquelle, Baden Baden, Germany	155
King's Well, Bath, England	115
Carlsbad (Sprudel), Bohemia	162
Saline, Bourhonne, Haute-Marne, France	149
Lorenzquelle, Leuk, Valais, Switzerland	123
Kochbrunnen, Weisbaden, Nassau, Germany	156

CHAPTER II.

THE USE OF MINERAL WATERS.

HISTORY.

From the earliest ages mineral and thermal baths have been considered of great importance in the maintenance of health and the cure of disease. Bathing was considered a sacred rite by the Egyptians, and the "washing in Jordan" and other streams, and in "pools" or springs, was made a religious duty by the Israelites. Their ceremonials included elaborate washing of the body and of various vessels. There was a celebrated bathing place near the Dead Sea which was a favorite resort of Herod.

The Greeks built the temples of Esculapius near some famous springs, and the Athenians took their summer "outing" at the sulfur baths of their "Saratoga," the island of Eubœa. The very name Thermopylæ recalls by its etymology the warm baths of this locality.

It is probable that there never was a nation that carried to such a degree the luxury and magnificence of bathing establishments as did the Romans. Their "thermæ," as they were called, were built from the time of Agrippa, B. C. 21, to that of Diocletian, A. D. 302. Wherever Roman supremacy was established there the warm springs were developed, or bathing resorts were created, without sparing of expense for conveniences and artistic embellishment. The hot springs establishment at Baiæ, near Naples, where the wealthy Romans congregated for health and pleasure, was a marvel of beauty and elegance. It is interesting to find still the remains of this period of Roman grandeur and wealth in distant lands, as in Bath, England; in Bagneres de Luchon, in the Pyrenees, in Aix, in Provence, in Paris, and Wiesbaden. After the Roman aqueducts were cut

by the advancing hordes from the north, the great bathing resorts were, many of them, allowed to fall into decay, and now their remains only are left to point to those days of luxury.

Early medical writers, as Hippocrates, Asclepiades, Celsus, and Galen, describe methods of treating disease by the external and internal use of water, and some of their methods are in use to-day. Vapor baths, especially for medicinal purposes, have been in favor among the people of Turkey, Russia, Ireland, Scotland, Japan, and Mexico. At the present time, in many of our popular resorts, the external use of water, under the advice of a physician, is considered as important as its internal use. Some waters, of course, are much better adapted to external use than for drinking. The invigorating effect of sea bathing has been recognized from the earliest times. For hundreds of years the noted bathing localities of England, France and Germany have been the center of the social life of Europe at certain seasons. In our own country, the waters of Saratoga, White Sulfur, Rockbridge alum, Bedford, Cresson, Hot Springs of Arkansas, California, and hundreds of other places, annually attract those who hope for renewed health from the use of those waters in agreeable surroundings and under medical advice.

EXTERNAL USE OF WATER.

The effect of a bath[17] depends on the temperature of the water. If the latter is high, say about 102° to 110°, the temperature of the body is increased about 3°; if the temperature of the bath is as low as 66°, it reduces the temperature of the body about 2° within ten or fifteen minutes. A temperature of 88° to 95° is considered indifferent, as it does not change the temperature of the system, and can be indulged in for a considerable time without any harm.

The cold bath reduces the frequency of the pulse, produces contraction of the capillary vessels of the skin, which becomes cool and pale, and a flow of the blood to the internal organs, viz., to the brain, lungs, kidneys, etc. But as reaction takes place, after a short while the skin becomes red, and the pulse normal, or even more frequent than before. The symptoms

17. Watering-places of Germany, Austria, and Switzerland, Edward Gutmann.

produced by the rush of blood to the internal organs, resulting from the action of the cool water, are these: Dizziness in the head, tremor of the limbs, oppression of the chest, and a small pulse.

Hot baths accelerate the circulation of the blood, produce a rush of blood to the surface of the skin, and an expansion of the whole quantity of blood contained in the blood-vessels, thereby causing congestions and profuse perspiration. Diseases occasioned by suppressed perspiration and morbid organizations are benefited by these baths. The stimulative effect produced by the high temperature of the hot water often proves very beneficial in cases of paralysis. The high temperature is probably the sole efficacious element of the mud, peat and sand baths which are so much patronized on the continent, both by physicians and patients, although the heavy weight of these substances may also contribute a good deal to their beneficial action in some affections, as enlargement of the liver, thickening of joints, etc.

Indifferent baths, which have a temperature of 88° to 95° F., do not have any material physiological effect on the circulation of the blood or on the nervous system; but the experience of many years has proved them highly beneficial in cases of nervous irritability, neuralgia, sleeplessness, hysterical spasms, etc.

Very young persons, and old ones, not being strong enough to bring on a speedy reaction, should not take cold baths; nor should decrepit persons, or invalids affected with severe disorders of the digestive organs or a high degree of nervous irritability submit to a cold-water treatment. Diseases of the heart, congestions and hemorrhages of the lungs, apoplectic dispositions, are also contra-indications to the use of cold water.

Water charged with carbonic acid produces a very pleasant, prickling or burning sensation on the surface of the skin, a flow of blood to the latter, and redness and fulness of the pulse; therefore, it seems that this gas, when used externally, acts as a stimulant on the skin. Some salts, as chlorid of sodium, chlorid of calcium, contained in many mineral waters, also pro-

duce a stimulating effect on the peripheral nerves. The stimulative action of the carbonic acid is quicker, but that of the salts lasts longer; these, after having penetrated the epidermis, seem to remain longer in the skin, and thereby to produce the stimulation of the nerves.

Alkaline waters have no more effect on the system than common water baths, their salts not being absorbed by the skin; they mollify the epidermis, thereby enabling us to remove impurities that accumulate on the skin, and they prevent the pores from being obstructed by the secretions of the sebaceous and sweat glands.

The general effects of strong mineral-water baths may thus be summed up: They increase the circulation of the blood in the skin, promote its nutrition, augment the secretions, and often produce eruptions on the skin.

INTERNAL USE OF WATER.

Early Opinions.—There was very much of mysticism and ignorance connected with mineral waters in ancient times. A river in Phrygia was believed to produce a certain kind of delirium in those who used it. Some waters whitened the hair of animals; others turned the wool of sheep black. Some waters, the people thought, caused loss of memory; others strengthened and sweetened the human voice. Waters there were that intoxicated the drinker, while others destroyed the taste for wine. Wine itself was said to flow from a certain spring, while a well in Asia Minor yielded water which burned. This latter was no doubt due to natural gas or petroleum which came from the well. It was thought that water after boiling was colder than unboiled water, and rain water was continually being poisoned from the vapors that came from the earth. Pliny held that water was more wholesome after boiling, which we know to be true now, for the lime, if present, would be precipitated by boiling and organic germs would be destroyed. He taught better than he knew.

Use of Waters at Home.—Says a prominent author:[18] "Natural mineral waters, securely bottled, being nowadays exported to

18. Gutmann, loc. cit.

all parts of the globe, many believe them to be fully as efficient when taken at the patient's residence as when drunk at the spring. This I believe to be a mistake. A regular strict treatment, as it is enforced by the physicians of a well-regulated watering-place, cannot be carried on at home. Business, family, old habits of living, and, more often, divers irregularities of living, prevent the patient from adhering strictly to the rules prescribed for the use of the waters; he would not rise early in the morning for the sake of drinking a few glasses of water; afraid of neglecting his business, he would not spend several hours of the day for necessary exercise; nor would he wish to have the diet of the whole family changed on his account, because the usual diet does not agree with the mineral water, and so on. Moreover, there are waters whose efficacy mainly depends on their natural high temperature. It would hardly be possible for the patient, however careful, to raise the heat of the bottled water every morning to exactly the same degree."

Action of Waters upon the System.—[19]"If you drink a large quantity of water which is not instantly absorbed, you feel oppressed as by a heavy weight. But absorption generally commences as soon as the water is taken, and, if the stomach is empty, goes on very rapidly. The water is absorbed by the veins of the stomach and the intestines, but more by those of the former; the secretion of the saliva, bile and urine is increased. The maximum of the absorption is reached about two or three hours after the water has been drunk, excretion by the kidneys being most abundant at that time. Water containing salts is not so rapidly absorbed as common water; the less salt it contains the more easily it is absorbed. The quantity of water which the stomach is able to receive and absorb is immense; persons are reported to have swallowed 200 and even 300 ounces of mineral water every morning for several weeks. The quantity of water in the blood varies according to the amount of water drunk and absorbed. A large quantity produces an expansion of the blood-vessels and an increase in the secretions of the skin,

19. Gutmann, loc. cit.

of the intestinal canal, and especially of the kidneys, which carry off the largest portion of the water. Much water-drinking diminishes the specific gravity of the urine, makes it thinner, and increases the quantity of the urine. The perspiration is also thereby increased, but this increase varies much, according to the temperature of the water and the air, and the active exercise of the person. Water, if properly administered, augments all the secretions of the system, and facilitates the change of tissue and the renovation of the body. Water of a high temperature is more easily absorbed, and is more efficacious than water of the usual cool temperature. Too much water-drinking impedes the digestion, disturbes the secretions, and often produces dropsy.

Water taken in large quantity expands the stomach, the intestines, the blood-vessels, the biliary passages, and the bladder; it liquifies the contents of the intestinal canal, and thereby promotes the evacuation; it facilitates the circulation of the blood in the smaller vessels of the liver, lungs, and spleen, thereby preventing or relieving congestions of these organs. The expansion of the biliary passages and the bladder by water greatly facilitates the passage of gall-stones and gravel.

Cold water is a stimulant, and as such highly beneficial in the treatment of atony of the stomach and the intestines, and of defective digestion caused thereby. It also diminishes the irritability of these organs.

Warm water is used with great benefit in many painful affections of the stomach and the intestinal canal. It fluidizes its contents more thoroughly than cold water, augments the secretions, and promotes the absorption of morbid deposits.

If mineral waters are drunk, the larger portion of them is also absorbed by the stomach. Especially are the gases which they contain rapidly carried into the blood, while the absorption of the mineral constituents is somewhat retarded. High temperature of the water and active exercise favor the absorption. Another portion of the mineral water passes through the alimentary canal, where it is partly absorbed, the rest being eliminated by the action of the bowels.

CHAPTER III.

THERAPEUTICS OF MINERAL WATERS.

ACTION ON THE SYSTEM.

The questions frequently asked are: "How do mineral waters act on the system?" "What particular value have they over pharmaceutical preparations containing the same ingredients?" A study of the theory of solution as recently developed (see chapter V) has led us to believe that in dilute solutions we have the chemical substances existing in the "ionic" condition. It is easy to understand that in this condition the medicinal substances are more readily assimilated by the system, or, in other words, that extremely dilute solutions will have a different therapeutic effect from more concentrated solutions.[20]

Mineral waters may be used, as previously noted, either externally or internally. Every extended treatise on the therapeutic action of such waters pays special attention to the use of the warm or cold bath as a curative agent.

In Kansas there are a large number of waters especially adapted to bathing, but, as the state is geologically remote from those sections where great folding and uplifting of strata have occurred, warm or thermal springs are not known.

SOME POPULAR FALLACIES.

It is generally admitted that mineral waters are particularly adapted to the cure of chronic or long-standing diseases. Doctor Anderson says:[21] "Mineral springs are not 'cure-alls.' As a rule too much is claimed for them. The many marvelous cures cited and the many improbable and ridiculous statements seen on printed circulars do more harm than good. Sensible people are not going to believe that a 'magnetic' mineral water is going to save a bad case of consumption, or that any 'mineral

20. North American Journal Homeopathy, (3) XIII, pp. 529-537.
21. Mineral Springs and Health Resorts of California, p. 12.

water' cures heart disease, etc. On the other hand, it would be quite as flagrant an error to suppose that all reputed beneficial effects of mineral waters were only the result of extravagant or interested imaginings. . . . To obtain the greatest possible benefit from springs, it is absolutely essential that the patient first consult his regular physician. . . . The indiscriminate use of mineral waters, either for drinking or bathing purposes, cannot be too strongly condemned; for while they look bland and harmless, they are potent therapeutic agents which may accomplish much good if judiciously employed, but may also do much harm and may be followed by serious if not fatal results in careless hands."

SCIENTIFIC USE OF WATERS.

"All we need at American health resorts and mineral watering-places is to follow the natural scientific regime which has been worked out for centuries in Europe. There every patient confides in his physicians, and medical men value the mineral springs more, apparently, than we do in America. The patient is ordered to this or that spring for two or three months. He places himself entirely under the care of his family physician and the resident physician at the springs. Patients who are able to walk get up at six A. M. and walk to the springs, drink the prescribed amount of water, and walk from one to two miles before breakfast. They take their meals regularly; their diet is carefully regulated for each disease. They retire early, exercise freely, use the baths or drink the waters regularly, and improve twice as fast in Germany, France, and England, for the same class of diseases and with the same—almost the identical—mineral-water treatment as we have in America, simply because they follow a regular scientific system."

In regard to the therapeutic action of the substances usually found in mineral waters, the author cannot do better than to quote from Doctor Crook:[22] "It may be said without fear of dispute that the most frequent, as well as the most important, component of a mineral spring is the water itself. Aside from its absolute necessity to the preservation of all forms of life,

22. Mineral Waters of the United States and their Therapeutic Uses, p. 39.

this agent possesses certain very important therapeutic properties, some of which may be considered at this time. When ordinary pure water is swallowed it is almost immediately taken up by the radicles of the gastric veins, passing directly to the liver, and from thence into the systemic circulation. Its manifold functions in the body are fully treated in works on physiology. For our purpose, it is sufficient to notice its influence on the emunctories. Water is actively diuretic, not only increasing the liquid flow of the urine, but, if taken in large quantities, greatly augmenting the amount of solids—urea, uric acid, etc.—escaping from the system in a given length of time. It thus aids in the process of tissue metamorphosis, and may be said, so to speak, to 'flush the system.' It also dilutes the urine, renders it lighter in color and specific gravity, and sometimes relieves it of irritating qualities."

Water in large quantities thus becomes useful in certain kidney diseases, characterized by stagnation of the renal circulation and suppression of the urine. It is also valuable in acid states of the urine, characterized by scalding on urination, and a frequent desire to empty the bladder, symptoms which are observed in numerous affections of the genito-urinary passages. In warm weather, water is also diaphoretic, and, aside from its grateful, cooling and refreshing effects, it thus has some influence as an antipyretic in febrile states of the system. According to Maillart, of Geneva,[23] typhoid fever may be treated internally by copious draughts as a definite method. Five to six quarts may be administered daily, during the whole of the febrile period, and there are no contra-indications. The good results which have been observed are no doubt due to oxidation of the toxins and refuse material, which are thus rendered soluble and eliminated. When taken cold in considerable quantities, water also stimulates the peristaltic action of the small intestines, and thus has a certain cathartic influence.

ADVANTAGES OF USING NATURAL WATERS.

Considerable has been written in regard to the action of natural mineral waters being entirely different from what could be

23. Revue du Med., March, 1894.

obtained from artificial preparations of the same ingredients. It is true that some ingredients may be present in small quantities, so small, in fact, that they are neglected by the ordinary analyst, and yet they may be present in large enough quantity as ions to have a therapeutic effect. Ordinarily, however, the taking of a mineral water is beneficial, more because of the conditions under which it is taken than because it is made in nature's laboratory rather than that of the chemist. The hygiene and climate of the surroundings of the mineral-water resort or sanitarium have a very important effect on the health of the patient. There are regular meals, and of food that is prescribed by a physician; there is sufficient exercise, especially in the open air; there is the freedom from care and business; there is pleasing scenery and society. All these, with the drinking of an abundant supply of water—a thing too often neglected at home—tend to improve the health of the patient, entirely aside from the beneficial effects of the water taken under the advice of a physician. If baths are also prescribed, they are of the right kind, temperature and duration to assist nature in its efforts to throw off a diseased condition. It is extremely difficult to have these conditions at home.

IONS ARE PRESENT IN SOLUTION.

According to the modern ionic theory, a large percentage of the ingredients of mineral waters are present as ions, because they are metallic salts in dilute solutions. When the waters are very concentrated, as in the case of the Crabana, Hunyadi, Carlsbad, and also the Abilena, of Kansas, it is fair to assume that some of the ingredients are undissociated (see chapter V). In general, then, it is necessary to consider the therapeutic action of ions of a certain kind, as Na, Ca, or SO_4, or of solutions in which we have a large variety of ions. In the latter case the therapeutic action of a given ion may be modified by the presence in the solution of others. In most cases we are compelled to consider the action of salts when at least two kinds of ions are present. The science of medicine has hardly progressed far enough, since the modern theory of

solution was proposed, to enable us to tell positively the action of ions of a single kind, in the absence of all others, except in a few cases.

LIST OF ELEMENTS.

The substances (ions) usually found in mineral waters are:

Positive, or base-forming.	Negative, or acid-forming.
Aluminum.	Arsenate.
Ammonium.	Borate.
Barium.	Bromid.
Calcium.	Carbonate.
Iron.	Chlorid.
Lithium.	Fluor.
Magnesium.	Hydrocarbonate.
Manganese.	Iodid.
Potassium.	Nitrate.
Sodium.	Phosphate.
Strontium.	Silicate.
	Sulfate.
	Sulfid.

Besides these there are some very rare ingredients found in such small quantities that their therapeutic action has not been studied.

ACID AND ALKALINE WATERS.

Waters are divided into three classes, as far as their reaction is concerned, namely, neutral, acid, and alkaline.

It is admitted that dilute acids and alkalies have an ion action, due to the presence of the characteristic acid hydrogen or of hydroxyl. They also produce osmotic changes and exert ordinary salt action. They also modify the process of digestion and absorption. Acids and alkalies are not absorbed as such in the body; if in the intestines they are neutralized by the carbonates, or in the stomach by the hydrochloric acid of the gastric juice. The system is so constructed that it can take care, for a time, at least, of an excess of acid or alkali. This is done by a change in the composition of the urine; so acids and alkalies are excellent diuretics, increasing the ammonia of the urine at the expense of the urea.

As acid salts have some of the properties of acids, it follows that mineral waters containing these salts would have some acid

characteristics. Acids in the stomach assist the action of the pepsin in digestion; they also increase the flow of the gastric juice. Acids are very useful in that variety of dyspepsia in which not enough acid is secreted.

"All acids convert proteids into acid-albumins, which are insoluble in moderately strong, but soluble in concentrated or very weak acids. Upon this precipitation of proteids depends their astringent action.

"Alkalies will reduce the acidity of the chyme, and thus increase the alkilinity of the intestinal fluids, even if they are themselves neutralized and absorbed before reaching the duodenum. In this way they may favor the emulsification of fats, and the action of the pancreatic ferments, if there is not sufficient alkali in the intestine." In a normal condition of the system, this action would be of no value, but where there is an excess of mucus, or too great acidity, the alkalies are very useful. On account of the action of the undissociated salt, the secretion of the urine is increased.

The free acids that are found in waters are sulfuric and occasionally hydrochloric. The sulfuric acid is derived from the oxidation of pyrite (FeS_2). The Rio Vinagre, in South America, is supplied by such acid springs, and it is estimated that it carries daily to the ocean an amount of acid equal to 82,720 pounds of oil of vitriol and 69,638 pounds of concentrated muriatic acid. There are some noted springs of this character, as, for instance, the Oak Orchard acid water, in New York, the Texas salt springs, and the Thermal acid springs of California. The Abilene, Kan., artesian well contains a notable quantity of free hydrochloric acid.

Waters of this class usually contain an abundance of such elements as iron and aluminum, so that their therapeutic properties may be considered as being due to these elements. "Being very astringent, the stronger acid waters are useful in relaxed states of the mucous membranes, especially when characterized by diarrhea and dysentery. They have also been used with great effect in hemoptysis, colliquative sweats, and in depraved

and impoverished conditions of the body, due to intemperance or specific diseases."

For chronic lead poisoning acid sulfate waters may be used, as they form with the lead an insoluble lead sulfate which passes from the system. Waters containing carbonates dissolved in an excess of carbon dioxid (carbonic-acid gas) are not included in this class, as, on account of the extreme weakness of carbonic acid and the fact that it so readily escapes, these waters soon react alkaline.

This carbonic-acid gas, however, is one of the most important chemical as well as therapeutic constituents of water. It not only renders many mineral substances soluble, but it gives the water an agreeable, pungent taste, and assists digestion, aids the flow of saliva, and allays gastric irritability.

The alkaline waters are extremely numerous, and their reaction is usually due, as noted above, to the escape of the carbon dioxid. The metal associated with the acid may be potassium, sodium, lithium, calcium, magnesium, or iron. As a class, according to Doctor Cross, "they form a very efficacious and speedy remedy in the treatment of acid dyspepsia and flatulence." They also act as stomachics, if given before meals, by stimulating the peptic glands.

Having a diuretic tendency, the alkaline carbonated waters tend to correct the acidity of the urine, and are of great service in fevers, rheumatism, gout, vesical irritation, diabetes, etc. In Europe they have long held high favor in the treatment of meritis, leucorrhea, as well as other female pelvic disorders. When combined with salines, as they often are, forming the great alkaline-saline groups of waters, and because they dissolve the mucus, they are of much value in catarrhal conditions of the gastro-intestinal tract with the engorgement of the portal system. They have further been found useful in obesity.

The lithontriptic value of these waters is well established. In many cases where there is a tendency for mineral material to collect around an organic nucleus these waters are useful, as they are alkaline, and dilute the urine and prevent the forma-

tion of calculi. In gout, as the excessive acid condition of the blood is modified, the uric acid is more readily eliminated.

Excessive acidity in the alimentary canal, which leads to gastro-intestinal catarrh, is benefited by the use of alkalies. If this acidity is in the stomach it may be neutralized by the use of waters containing sodium bicarbonate; if in the intestine, and cathartic action is not desired, calcium bicarbonate or calcium phosphate can be employed.

THERAPEUTIC ACTION OF INDIVIDUAL ELEMENTS.

A.—Base-forming Elements.

Aluminum is not often present in large quantity in waters that are used for drinking, but, as previously noticed, it is a common constituent of acid waters, like some of the alum springs of Virginia. Comparatively little can be said of the action of the aluminum ion, but the alums are used locally as astringents, and internally in gastric catarrh, enteralgia, gastralgia, lead colic, etc.

Ammonium is not present in large enough quantities to produce any decided effect, as far as known. In fact, since it is produced by the decomposition of organic matter, sanitary chemists are disposed to look upon it with suspicion, as indicative of contamination of the water. This is not necessarily the case, however, because some waters have been found containing ammonium salts as a natural constituent. From a study of the ammonium ion, it is evident that it has a marked action on the secretions, especially saliva, mucus, and sweat. It is used as a local expectorant, and as a stimulant of the respiratory centers, for cough and asthma.

Barium, in its ion actions, resembles the organic groups. Its most important systemic action is a slowing of the heart and a rise in blood pressure. It is said that when barium is given in very dilute solutions the amount absorbed is very small, and is deposited in the bones. It may be of use also in the treatment of cancerous, scrofulous and other morbid growths.

Calcium compounds are very abundant in mineral waters. The carbonates are very alkaline in action, and in large doses

may cause constipation. They are used in chronic diarrhea. They are also used with advantage in cases of uric-acid gravel and calculi. Calcium chlorid is said to have a diobstenent effect, and to promote the secretion of urine, perspiration, and mucus. The use of water containing it is recommended in "scrofulous diseases, and in chronic eczema and impetigo, connected with a lymphatic temperament."

Calcium sulfate is one of the chief constituents in water that make it permanently "hard." It is not considered of any special advantage in waters, though perhaps such waters might be used where there is not sufficient lime in the bones.

[24] "The importance of the calcium ion arises from the fact that it is a universal constituent of protoplasm, only a few of the lower fungi being able to dispense with it. It appears to be mainly fixed in the nuclei, while in the extra-nuclear portion its place seems to be taken by magnesium. It appears to be essential not only to the living protoplasm, but also to inorganized ferments. Calcium, as well as potassium, seems to be essential to living protoplasm. . . . The gradual withdrawal of calcium from the body, by withholding it from the food, leads, in animals, to effects which closely simulate those of rickets and osteomalaria. There is, however, some difference. In calcium starvation but little bone is formed, yet this contains the normal amount of calcium. In rickets the amount of bone is even excessive, but it is very poor in calcium. In man these conditions are characterized by a diminished amount of calcium in the bones. The thought lay near at hand to employ calcium, particularly calcium sulphate, in the treatment of these diseases, but the results have been somewhat disappointing, as might be deduced from theoretical considerations. The condition is somewhat similar to that existing in chlorosis, for, except in the experimental disease, the cause of the disorder is never to be found in the inefficient supply of calcium salts, since the amount of these in the organism is always more than enough to supply the organism. The real cause must be sought in the abnormal absorption or utilization of these ions.

24. Text-book of Pharmacology, Sollman, page 569.

. . . Calcium salts have also been given in hemophilia to increase the coagulability of the blood. Although the last word has not been spoken on this interesting subject, it would seem that hemophilia is not usually dependent on the deficiency of lime salts. Nevertheless most clinicians report very favorable results. Further than this, there would not seem to be any rational therapeutic indications for the calcium ion, the calcium salts only being useful on account of the acids with which they are combined or by virtue of their alkaline action."

Iron is regarded as one of the most useful substances to be found in a mineral water. As it is found in the hemoglobin of the blood, and as it occurs in the lymph, chyle, gastric juice and other liquids of the body, it must be extremely important in the animal economy. Chalybeate waters[25] "produce a constructive metamorphosis, creating more red blood corpuscles, thereby increasing the specific gravity of the blood and of the bodily weight, reproducing a healthy glow and the rosy cheek on the faded and bleached-out face." By the use of the hemoglobometer, it has been shown that "the deficiency of the coloring matter of the blood, observed in anemic states, may be readily made up by the administration of a carefully selected chalybeate water. It matters not though iron be present in small quantities, and few of the carbonated iron waters contain more than five or six grains per gallon. The blood contains normally about forty-five grains of iron, and this quantity cannot be permanently increased by consuming large quantities. It is probable that the deficiency, no matter how produced, never exceeds fifteen or twenty grains."

The tendency, then, is to increase the appetite, promote digestion, and relieve a languid or depressed condition of the system. Though the iron occurs sometimes as sulfate and chlorid, yet the most common combination is the bicarbonate, and this is supposed to be the form in which it most readily enters the circulation. For special notes on the occurrence of iron in mineral waters, see Part II. . "The indications for the use of the iron waters are numerous. In slow convalescence from acute dis-

25. Mineral Waters of the United States, Crook, page 49.

eases, the anemic states resulting from a severe operation or difficult confinement, in all forms of hemorrhage not due to fulness of the vessels or fragility of their coats, in amenorrhea when due to chlorosis, in the debilitating catarrhs of the uterus and vaginal mucous membrane, and in the various cachexias, the chalybeate waters may be confidently expected to render valuable aid." Those who are of a plethoric habit, or who are troubled with vertigo, should avoid the use of iron waters.

A number of theories have been advanced to explain the action of iron on the system. Among others may be mentioned the theory that it is of value because of the direct absorption and gradual utilization of the iron, whether the substance given is a body that dissociates with iron as an ion, or whether the iron is only a constituent of an organic body or of the food. Another theory is that iron given in an "organic" form can be absorbed, but inorganic iron simply stimulates digestion and absorption, and does not itself enter into the blood. It seems to be pretty well established that organic iron may become a part of the hemoglobin, and inorganic iron, while incapable of this change, assists the organism to utilize the organic iron, so both kinds of iron are of value. The term "chalybeate" has been applied to iron waters from the name of a very ancient people, the Chalybes, who worked in iron.

Lithium is a rare ingredient in mineral waters, but those that contain it have acquired considerable reputation in the treatment of disease. It is usually considered as present in the form of carbonate or bicarbonate, mixed with carbonates of the other alkalies. It is probable that many of the so-called lithia waters contain too small a quantity of this ingredient to be of any therapeutic value. As first pointed out by Andrew Ure, lithium forms a soluble salt with uric acid, and this has led to the extensive use of lithia waters in cases of uricemia. For uric acid, sand, gravel, and calculi, and in gout and rheumatoid anthritis, as well as in phosphatic deposits in the appendix, and in concretions, lithium waters have been used with success. As an ion, lithium has an action midway between that of potas-

sium and sodium. It has a tendency to increase the excretion of nitrogen.

Magnesium has a characteristic action on the system. As carbonate, it is useful in "acid eructations and pyrosis, and in sick headaches, when accompanied by constipation. It is also of value in checking the formation of uric acid gravel and calculi." This latter action is no doubt due to its alkaline character. As chlorid, magnesium is often found in saline waters and brines. It is useful to increase the flow of bile, and as a mild purgative. It is as a sulfate, however, that we are most familiar with the action of magnesium. Like sodium sulfate, it promotes the process of endosmosis and exosmosis, and, by abstracting the watery elements of the blood, increases the intestinal secretions. "Even if the quantity is small, it will tend to promote regularity of the bowels when taken continuously. The best results are observed in disordered conditions of the stomach, liver, and bowels, with concomitant symptoms of constipation. In sluggish states of the liver, characterized by a sallow countenance, yellowness of the conjunctiva, coating of the tongue, and hemorrhoids, the sulfated saline waters are speedily efficacious."

In eliminating the various chronic infections from the system—scrofulous, syphilitic, and malarial—as well as in expelling lead, mercury, and other metallic poisons, they furnish us important and useful applications. For purgative effects, physicians recommend that the waters be taken on an empty stomach, before breakfast, and that a brisk walk in the open air follow the drinking of the water. These waters should not be taken when there is a chronic inflammatory condition of the stomach or intestines, or in case of general debility.

It seems probable that the magnesium in water acts as an undissociated salt, as, although soluble, the magnesium ion is incapable of absorption into the blood. "Magnesium[26] is practically the only non-absorbable cation which can be used as a cathartic. Why certain ions should be capable of absorption, and others not, cannot be satisfactorily explained." Magne-

26. Text-book of Pharmacology, Sollman.

sium salts are converted into acid carbonates in the small intestines according to the equation:

$$MgSO_4+Na_2CO_3+H_2O+CO_2=MgH_2(CO_3)_2+Na_2SO_4.$$

It is quite immaterial what particular salt be given, as the hydrate, chlorid or sulfate are all converted into the carbonate. However, in the case of the sulfate, the sodium sulfate which is formed is, of course, also a cathartic; so the effect is doubly large. The hydrate and carbonate, on the other hand, possess also the action of alkalies.

Manganese is not a very common ingredient in mineral waters, or at least it is present in so small a quantity that it is not often reported. There are some waters, however, in which it is present in notable quantities, and one or two that are strongly impregnated have been recently found in Kansas. In most analyses the manganese is considered to be present as bicarbonate or sulfate. As manganese is normally present in the blood, it might be supposed to be of considerable value therapeutically, and, indeed, much is claimed for it by some. It promotes the flow of bile, and is no doubt useful on account of its tonic and reconstructive properties. It is so often associated with iron in mineral waters that we have not often an opportunity to study its action alone. Recent authorities claim that manganese is not absorbed at all into the system, unless given in corrosive doses.

The *Potassium* ions seem to have no special therapeutic action, as they are so rapidly excreted. Potassium compounds are quite similar to those of sodium. As carbonate, it corrects acidity and acts as a diuretic in connection with other alkalies.

Sodium salts are very abundant in waters, on account of their great solubility. As sodium and chlorin ions possesss very slight toxicity, their combinations are chosen when the action of other ions is to be studied. In some waters the carbonate and bicarbonate is very abundant. As sodium carbonate is found in the blood, saliva, urine, and other fluids of the body, it would be thought to be of importance in substances taken into the body. Sodium-carbonate waters have the general prop-

erties of alkaline waters, and are the best for use when alkaline waters are indicated. There are no waters in Kansas that at all correspond to the Saratoga waters, for instance, in abundance of carbonated alkalies. Their effect on the system can hardly be ascribed to the presence of the sodium ion, or to the potassium ion, which is often present. They have a marked action on the mucous membranes and increase the secretions. As previously noticed, catarrhal conditions of the stomach or intestines, especially when accompanied by chronic diarrhea, or when there is too great acidity in the alimentary canal, may be treated with success by waters containing sodium carbonate. The activity of the skin and kidneys will be increased. It is by some asserted that diabetes may be successfully treated with these waters, and sugar may be caused to disappear entirely from the urine.

Sodium as a chlorid is even more abundant than sodium carbonate. As brines are common either in the surface springs or in the deep bored wells, there is no ingredient of more importance. Most authorities assert that salt is actually necessary for a healthy growth of the body, as it is a constituent of almost every structure. It has much to do, no doubt, with the regulations of exudation and absorption, and assists in maintaining the fluidity of the albuminoids in the blood. As so many of the effects of these waters are no doubt due to the chlorin ion, rather than the sodium, the further consideration will be deferred until chlorin is discussed.

Strontium, though found in small quantities in a few waters, has, so far as known, little therapeutic value. In general, it resembles barium, although somewhat weaker in its action. It is suggested that, "being an intestinal antiseptic, however, it is possible that considerable quantities of the strontiated waters might be found useful in flatulence, intestinal torpor, summer diarrhea, etc." It is usually considered as present in the form of bicarbonate, accompanying similar salts of calcium and magnesium. "In dilute solutions only very small amounts are absorbed from the stomach; none from the intestines, since it is

converted into phosphates, in which form it is generally deposited in the bones."

B.—Acid-forming Elements.

The acid-forming elements or ions have necessarily, to some extent, been discussed above, as there have not been enough experiments to "pick out," so to speak, the therapeutic action of the acid from the base.

Arsenate waters are not common, though a small quantity of arsenic in water might make it a valuable remedial agent on account of its action as an alterative. According to Doctor Anderson,[27] "Arsenical waters have proved highly beneficial in irritative dyspepsia, chronic gastric catarrh, gastralgia and entralgia. Jaundice with catarrh of the bile ducts and chronic cirrhosis of the liver are improved by these waters. The waters are highly extolled in chlorosis and anemia, chronic malarial toxæmia, hemicrania, and malarial neuralgia, and in cutaneous diseases, scrofulous sores, and syphilitic contaminations. The skin diseases most benefited are the chronic scaly variety—especially psoriasis, eczema, pemphigus, and old cases of acne. For these diseases the waters containing both iron and arsenic are especially serviceable, taken one hour after meals. Menorrhagia and functional impotence are also improved by a course of these arsenated and chalybeate springs, with wholesome food and free outdoor exercise." Arsenical waters would be most naturally found in mineral localities where such metals as antimony, copper, bismuth, cobalt and nickel occur.

Borates occur abundantly in the waters from some localities, and they are found in small quantities in brines and associated with alkaline waters. Borax or sodium borate is the combination usually reported. In California large quantities are obtained commercially. The water may be used in "renal and vesical catarrh depending upon the uric acid diathesis." It has also been found useful in clergymen's sore throat, alleviating the inflammation, and strengthening the vocal cords. As a gargle the water is very useful. Boric acid and borax are

27. Mineral Springs and Health Resorts of California, page 26.

used in the preservation of food, and they are probably less injurious than other substances.

Bromids occur especially in brine, associated with chlorids and sometimes iodids. It is evident that the therapeutic value is directly connected with the bromin of the associated salt, for quite similar effects are obtained whether the positive element be sodium, potassium, or some other metal. The bromids are more soluble than the chlorids, and this fact is taken advantage of by crystallizing out the salt ($NaCl$) first, and using the mother-liquor for the commercial manufacture of bromin. Bromin is very often associated with magnesium in mineral waters.

These waters are essentially alterative, and are used in the treatment of rheumatism, gout, goiter, etc. As they hasten retrograde tissue metamorphosis, they are of use in diminishing the weight of the body. In cases of poisoning with mercury or lead, bromides have been used with success. As sedatives, to relieve wakefulness and over brain work, and in cases of epilepsy, these waters are recommended, and since they promote absorption and elimination of used-up material, bromin waters can be utilized in the treatment of scrofulous tumors, ulcerations, and chronic cutaneous diseases.

Carbonate waters have been discussed under alkaline waters, as, so soon as the gas escapes, the waters show an alkaline reaction. The gas carbon dioxid itself, however, when dissolved in water, is agreeable to the taste, and very often grateful to the stomach. The very extensive use of artificial carbonated beverages, "soda-water," sweetened and flavored, it is true, shows the favor in which a solution of this gas is held. Except in a general way, little is known in regard to the action of carbon-dioxid gas, for in most waters it is assumed to be present to form alkaline carbonates. The activity of carbon dioxid is not destroyed by neutralization, as is the case with other acids. "When absorbed it is fixed in the form of sodium bicarbonate, which is dissociated so readily that it acts both as an acid and an alkali. It has a somewhat specific effect in diminishing vomiting. On account of the stimulation of the sensory nerves

of the mucous membranes with which it comes in contact, it is a general reflex stimulant."

[28]"In moderate quantities, it stimulates the flow of saliva, aids digestion, slightly accelerates the pulse, renders the mind clear, and the person cheerful. The imbibition, however, of large quantities, causes sickness, vomiting, headache, vertigo, a tottering gait, and even asphyxia." Bathing in water charged with carbon dioxid causes a prickling sensation, which lasts for some time, and persons in health, on leaving the bath, experience a pleasing exhilaration, and the inclination to muscular activity is greatly increased.

Chlorids are as abundant as sodium in waters, and it is probable the therapeutic effects of common salt are due to the chlorine ion rather than to the sodium. Sodium chlorid, when taken into the system, increases the flow of the gastric juice, bile and pancreatic juice, stimulates the appetite, and assists digestion. Waters containing it possess a slight aperient effect, and it tends to prevent putrefactive changes. The quantity of urea excreted and the secretions from the bronchial tube are increased. So, for gastric, hepatic and intestinal disorders the salt waters are useful. This is especially true where there is an insufficiency of digestive fluids, with dry stools, a furred tongue, and disagreeable taste in the mouth, with loss of appetite. On account of their strong diuretic action, these waters may be used in cases of rheumatism, gout, and scrofula. When other positive ions, as well as sodium, are present, the action of the chlorin ion is modified. This may be seen in the case of magnesium chlorid, which has more marked cathartic properties than has sodium chlorid.

There is frequently more *Fluorin* in mineral waters than has been reported. This is because chemists regard it of so little importance that they neglect to test for it. Chas. Lepierre has recently shown that in the waters of the north of Portugal as much as twelve millegrams per liter of fluorin is sometimes found. Its therapeutic action is not well understood.

The *Hydrocarbonate* or acid carbonate in some cases indicates

28. Mineral Springs of the United States and Canada, Walton, page 63.

the condition of the ions when under pressure, for when this pressure is relieved some of the carbon-dioxid gas escapes and only carbonates are present. It is due, as has been previously stated, to the excess of carbon dioxid that such salts as calcium and magnesium carbonates are dissolved. The "acid carbonates" thus formed play an important part in digestion and absorption.

Iodids, although occurring usually with chlorids and bromids, are considered more active therapeutic agents. Their action is quite similar to that of the latter. They find their most useful application in treatment of chronic bronchitis, catarrhs, rheumatism, and in other chronic disorders. These waters have long been celebrated for their alterative character. In fact, some such springs were recommended for the cure of scrofula, obesity, etc., before it was known that they contained iodin. When there is stomachic irritation and acute inflammation these waters are contra-indicated, as they will do harm rather than good. Although the quantity usually found is small, seldom as much as one and one-half grains of the potassium or sodium salt in a gallon of water, yet the amount is sufficient to produce a decidedly beneficial effect on the patient for whom such waters are indicated. This would seem to confirm the theory that in many cases the ions of a substance are extremely active, and in just the condition to act therapeutically upon the system.

Some authors believe that there is little evidence of ion action in the case of iodin, such as exists in bromid, but that the effects are due to the undissociated salts, especially in the case of potassium iodid. Doctor Sollman believes that since this salt is extremely diffusible and penetrates so rapidly into the cells, and as it contains two of what he calls "foreign molecules," the liberated iodin ion may very likely combine with the proteids, substituting itself for the chlorid. It is also to be noted that the iodid readily decomposes with the separation of free iodin and hydriodic acid, both of which are irritants and tend to form another class of bodies with the proteids.

The iodin tends to remain a long time in the body, probably

on account of its combination with the proteids. It is believed that the iodin, combined into an organic compound, is excreted in the urine.

The iodids are used with success in the third stage of syphilis, but it is not known at present whether this is due to ion action or to the general action of the undissociated salt. There is similar doubt in regard to the way in which the iodids act in chronic rheumatism and asthma.

The *Nitrates* act both in the ionic condition and as undissociated salts. As the action in the ionic form is largely upon the mucous membranes, this may result in gastritis, in diuresis and perhaps nephritis at the place of exit. We are most familiar with the salt potassium nitrate, but it must be borne in mind that the action of this salt upon the system is not due to that of the nitrate ion alone; in fact, the potassium ion increases the action of the nitrate. This salt would act more strongly than the sodium nitrate. While nitrates are to some extent reduced in the body to nitrites, this action takes place so slowly that the action of the latter is not perceptible.

Nitrates are so seldom present in water in any quantity, that the action of these waters on the system has not been studied. We know that nitrates are poisonous if taken in large quantities, and even in small amounts they no doubt have some effect on the system.

Phosphates also are not often found in notable quantity. With the exception of the alkaline phosphates, the salts are usually insoluble. Sodium phosphate has a somewhat cathartic action. The calcium phosphate might be useful to increase the quantity of lime salts in the body.

Silicates are usually mentioned in reports on mineral-water analysis, but very often the analyst makes no distinction between the insoluble suspended matter and the true silica which may be in solution. It is a well-known fact that alkaline waters, especially if warm, have a tendency to dissolve silica from the rocks and soil, thus producing sodium or potassium silicate. When the water is evaporated with an acid this silica is rendered insoluble and separates out. Waters that are strongly siliceous

"petrify" wood or other substances which are placed in them. One author states that siliceous waters, taken internally, are useful in cases of cancer and leprous ulcerations, and it is also stated that by the use of these waters albumin and sugar have been made to disappear from the urine.

The *Sulfates* are of great importance, as has been previously stated in the discussion of sodium and of magnesium sulfate. It is evident that the sulfate ion has a therapeutic value, for we see it in such salts as sodium sulfate and magnesium sulfate; salts which have a distinct cathartic action. It is difficult to study the action of the sulfate apart from the metallic ion. It must be admitted, however, that the sulfate, etc., acts as a purgative. Sulfates are useful, as mentioned under magnesium, more from their action as undissociated salts than from any action as ions. Although the sodium sulfate has a bitter taste, it is of great importance as a constituent of mineral waters like the Abilena. Sodium sulfate, when entering the system through intravenous injection, produces a copious diuresis. The discussion of the sulfate as occurring in acid waters may be found on page 51.

Sulfur is an ingredient of a large number of waters. We are familiar with the characteristic odor of hydrogen sulfid, sometimes compared to decayed eggs. In mountainous volcanic regions, springs containing sulfids, sulfates, common salt and other ingredients are frequently found. There is often seen in the spring, or in the water that escapes from it, a white or yellowish deposit of sulfur, and by the precipitation of sulfur the water has a milky appearance. This is due to the oxidation of the hydrogen sulfid by the oxygen of the air, water being formed. The separated sulfur after a time settles to the bottom of the vessel in which it is drawn. In the southeastern part of Kansas, where deep wells are used as a source of water-supply, the sulfur water which is pumped up is allowed to stand in reservoirs till the excess of gas has escaped or been oxidized and most of the sulfur has settled.

Doctor Schweitzer,[29] in discussing the therapeutic action of

29. Mo. Geol. Surv., III, p. 36.

these waters, says: "To attempt an explanation of the medicinal effects of sulfur water is difficult, and apt to result in disappointment. That such waters are potent in their effects upon the skin, the mucus membrane in general, and those of the air passages in particular, as also upon the liver and the whole portal region, is demonstrated in many cases. It is likewise known that the efficacy of such waters does not depend so much upon the free sulfureted hydrogen gas which they contain as upon the sulfids and perhaps other sulfur compounds from which, after their getting into circulation, sulfureted hydrogen is evolved. The free gas, inhaled, or in solution in water, taken into the stomach, rapidly leaves the body without producing any apparent effect, while, when eliminated from sulfids that had entered into circulation, it manifests its presence by the appearance of a characteristic absorption band in the blood, and also by its quick and powerful effects upon the organism at large. Waters, therefore, which contain soluble sulfids—a rather unstable and easily decomposable class of bodies—are of much greater therapeutic value than waters merely rich in gas, although that gas be chiefly sulfureted hydrogen."

Some authorities believe that these waters have an alterative action, equal to that of mercury in syphilitic diseases. Sulfur water no doubt has a marked action on the liver, and assists this organ in the production of bile, which in turn assists so materially in digestion; hence, it is used in the treatment of chronic malarial diseases where there is a tendency to enlarged spleen and liver, hepatic congestion, and accompanying symptoms.

Sulfur waters have been used with success in rheumatism, gouty inflammation, and chronic joint injuries. They are especially valuable in such cases when used in the form of a hot or mud bath. Many people afflicted with cutaneous diseases are greatly benefited by bathing in these waters and at the same time taking them internally. Medical treatment with sulfur waters should be taken under the advice of a competent physician, as, if too long continued, they may have a destructive action on the system.

As free sulfur acts only to the extent to which it is converted into sulfids—a slow process—the irritation produced by the direct use of free sulfur is mild but prolonged, and this is true in the intestines, where it is dissolved by the sodium carbonate, as well as on the skin. In mineral waters some of the sulfur separates out on standing, as noted above, so free (molecular) sulfur would be present in the stomach soon after drinking the water. Only a little of this would be dissolved, but this would be expected to produce a mild cathartic action. As the sulfids are oxidized in the body and eliminated as sulfates, it is asserted that if taken into the stomach they do not produce any systemic ion action.

OBJECTIONS TO THE USE OF MINERAL WATERS.

It is sometimes urged against the use of mineral waters that this involves a kind of "polypharmacy," or that a large number of substances are administered when we really desire to get the effect of only one or two. The same thing, however, might be urged against the use of many organic drugs, for here we have a large number of substances present, and we only want the effect of a few with which we are particularly conversant. Again, it has been urged that we do not fully know the composition of the mineral waters that we prescribe; but this is also true of many drugs; so the objection is not a valid one.

CHAPTER IV.

BRINES AND THEIR INDUSTRIAL USE.

DEVELOPMENT OF THE SALT INDUSTRY IN AMERICA.

About the middle of the seventeenth century the Jesuit missionaries, in making journeys among the Indians, in what is now part of the state of New York, heard of certain springs which were regarded with superstition and said to contain demons. Several of these springs were pointed out to the missionaries, and salt was manufactured from the waters by the Indians and traders.

In 1788 the systematic manufacture of salt was begun in the vicinity of Syracuse, and the following year the output of this region was about 200 barrels. Afterward, a premium was offered by the state for any salt produced on the New York reservation. After rock salt was discovered beneath the surface, in 1878, the manufacture of salt from brines became a great industry in central New York. At the present time salt is produced in large quantities in Michigan, Pennsylvania, Ohio, West Virginia, Louisiana, Nevada, Utah, California, and Kansas.

Salt in Kansas.

Large areas of the state of Kansas contain salt on the surface or within drilling distance. The principal region, however, is near the middle of the state, extending entirely across from north to south.

The salt is found: First—as brines in salt marshes, which leave salt on the surface by evaporation in the dry season, producing the so-called salt plains; second—rock salt, which is found at varying distances beneath the surface; third—the greater part of the Permian and Coal Measure shales, in the eastern part of the state, have so much salt in them that the

water obtained from deep wells is quite strongly saturated with salt and other mineral substances.

Salt Marshes.

The salt marshes are found in a zone trending a little east of north and west of south from Republic county to Barber county, and to the Cimarron in Oklahoma.

In Republic county there are two interesting marshes, Tuthill and Jamestown. There are two salt marshes in Mitchell county, near the southern border, and two near the northern border of Lincoln county. Stafford county likewise has two marshes; while south of Harper county, in Oklahoma, there are several salt marshes that were well known to the Indians and earlier settlers of the territory.

Rock salt exists beneath a large area in Ellsworth, Barton, Rice, McPherson, Stafford, Reno, Pratt, Kingman, Sedgwick, Harper and Sumner counties.

The extent of the distribution of salt in the underlying strata of the state may be gathered by reference to the following analyses of brines from various localities:

	Parts of salt per 1000.
Well, Greenwood county, contains	6.9
Geuda springs, Cowley county	7.4
Well, Allen county	16.7
Well, Wyandotte county	25.7
Lake, Meade county	42.8
Well, Douglas county, 1300 feet deep	49.7
Well, Barton county	54.5
Well, Pawnee county, 755 feet deep	57.8
Well, Montgomery county, 1091 feet deep	59.4
Well, McPherson county	187.0

The pioneer salt manufacturer was a Mr. Tuthill. The scene of his operations was in the marsh previously referred to, in Republic county. In the fall of the year the water is generally nearly all evaporated, and the edges of the marsh are dry, and covered with a hard, thin scale of impure salt. Towards the center of the marsh the surface is more moist, and the scale of salt less thick and solid. [30]"This deposit is said to cover about 1000 acres. When the sun is bright, and shines upon the en-

30. Salt in Kansas; its Composition and Methods of Manufacture. E. H. S. Bailey, Reports Kansas State Board of Agriculture, vol. XIII, pp. 168-180.

crusted soil in the distance, the appearance is like that of a chain of lakes, and, indeed, a much closer inspection is necessary to destroy the illusion. A stream of fresh water flows in from the east, but after running a short distance it entirely disappears, nor does it dissolve very much saline matter in its course. Except in the rainy seasons, the marsh consists of 'hummocks' and dried-up lake basins, incrusted with mineral salts.

"The saline incrustation is thick after a period of drought, but ordinarily it is thin, and, in some places, *plumose*, as if brought to the surface by the moisture of the soil. The incrustation found on the Tuthill marsh is quite similar in composition to the alkali waters of the Western plains. The soluble part of this substance has the following composition, as shown by an analysis made in the laboratory of the State University:

"Iron and aluminum oxids	.13
Calcium sulfate	.99
Magnesium sulfate	1.29
Sodium carbonate and organic matter (undetermined)	3.56
Sodium sulfate	21.98
Sodium chlorid	71.82
Insoluble residue	.23
	100.00

[31]"In the manufacture of salt, Mr. Tuthill would collect the salt scales from over the marsh and dissolve them in water, allow the earthy impurities to subside, and siphon off the clear brine and evaporate it to dryness to recover the salt and other impurities. When the weather was not favorable for the formation of salt scales over the marsh, he would dip or pump the brine from small wells and haul it to his little salt factory. The brine was evaporated from large kettles in much the same way that our fathers evaporated sugar water in Indiana, Ohio, and the Eastern states. At present this seems like a very primitive method, but at that time it was in accordance with the most approved process. Portions of the arch of Mr. Tuthill's kettle salt plant still stand to mark the spot of his primitive factory.

"In the early sixties Mr. Tuthill made salt and hauled it to

31. Mineral Resources of Kansas, 1898, E. Haworth and M. Z. Kirk.

The Solar Process Salt Plant of Solomon City.

Manhattan, where he received as high as ten cents per pound for it. Mr. Hazen says he sold over 100 barrels of salt made by Mr. Tuthill and other farmers from 1873 to 1876, while he kept a store in Seapo.

"This marsh and other similar ones of the state were of great value to hunters in early times. They would come here to "jerk" their buffalo meat. In case they were in too great a hurry to wait to evaporate the brine and get the crystallized salt, they would dip the meat and hides into the strongest pool of brine and then dry them in the sunshine or by a fire. When a considerable quantity of meat was to be "jerked," they would cut the meat into long strips, boil the brine in kettles hung over a fire of buffalo-chips, dip the meat into the strong, hot brine, and lay it out to dry in the sunshine or on a lattice-work made of green poles supported on four posts, with a fire under it. In this way 200 or 300 pounds could be cured in five or six hours.

"Previous to the admission of Kansas into the Union the salt marshes were thought to be of great value, and by act of Congress twelve salt springs were donated to the new state, at the time of her admission, the same to be located by her commissioners. These were all located on marshes where there are no flowing springs, and subsequently these reserves became a part of the endowment of the State Normal School."

Some important brine wells are located at Solomon City, in Dickinson county. The attention of prospectors was called to this deposit on account of a salt spring just west of town, and, in 1867, C. W. Davis, of New Bedford, Mass., drilled a well here which produced excellent brine. Several other wells were drilled, striking brine at from 84 to 100 feet from the surface. With varying fortunes different companies have been manufacturing salt at Solomon City up to the present time. The capacity of the Solomon Solar Salt Company is about 7000 barrels a year.

ROCK SALT.

There are several places in the state where the vast deposits of rock salt are mined directly. At Lyons a shaft was sunk in 1890, and a factory was built for preparing the different grades of salt for the market. This shaft is about 1000 feet deep.

At Kanopolis, on the Union Pacific railroad, a salt mine has been in successful operation for more that ten years. At Kingman there were two salt mines which did a thriving business for several years.

Composition of Rock Salt.

For purposes of analysis care was taken to get average samples of the stock. The samples were thoroughly heated, to drive off all moisture, before the analysis was made. In commercial salt there is often considerable moisture, as it is so readily absorbed from the air, and this moisture, of course, makes the salt by so much the less valuable. We should not expect to find so much moisture in coarsely ground rock salt as in evaporated or finely ground salts. The probable combinations of bases and acids are given. The Kingman salt has the following composition (analysis by E. H. S. Bailey and E. C. Case):

	I.	II.	III.
Sodium chlorid	97.51	99.87	99.44
Insoluble residue	.20	.01	.09
Calcium sulfate	1.51	.07	.07
Sodium sulfate	.57	......	.28
Magnesium chlorid	.10	.05	.12
Iron oxid	.11	......	......
Totals	100.00	100.00	100.00

That from Lyons has the following composition:

	I.	II.	III.	IV.	V.
Sodium chlorid	96.85	97.39	98.20	99.78	97.95
Insoluble residue	.08	.09	.02	.01	.14
Calcium sulfate	.97	2.02	1.25	.08	1.70
Sodium sulfate	2.00	.46	......	.10	Trace
Magnesium chlorid	.07	.02	.02	.03	.14
Calcium chlorid	......	......	.51	......	......
Iron oxid	.03	.02	......	.55	.07
Totals	100.00	100.00	100.00	100.00	100.00

Here the vein that is worked is more than eight feet thick. It will be understood that numerous other veins of excellent quality are pierced by the shaft before the depth noted above is reached. These veins are separated from one another by soft shale or clay, and might many of them be worked to advantage.

An analysis of Kanopolis salt given below shows that it also is extremely pure:

	I.	II.	III.
Sodium chlorid	97.94	97.23	96.99
Insoluble residue	.13	.08	.29
Calcium sulfate	1.78	2.04	2.60
Sodium sulfate	.10	.41	......
Magnesium chlorid	.05	.24	.12
Total	100.00	100.00	100.00

EVAPORATED SALT.

The brine used for making salt is evaporated either by the solar process, as at Solomon City, or by the use of artificial heat, as at Hutchinson and elsewhere.

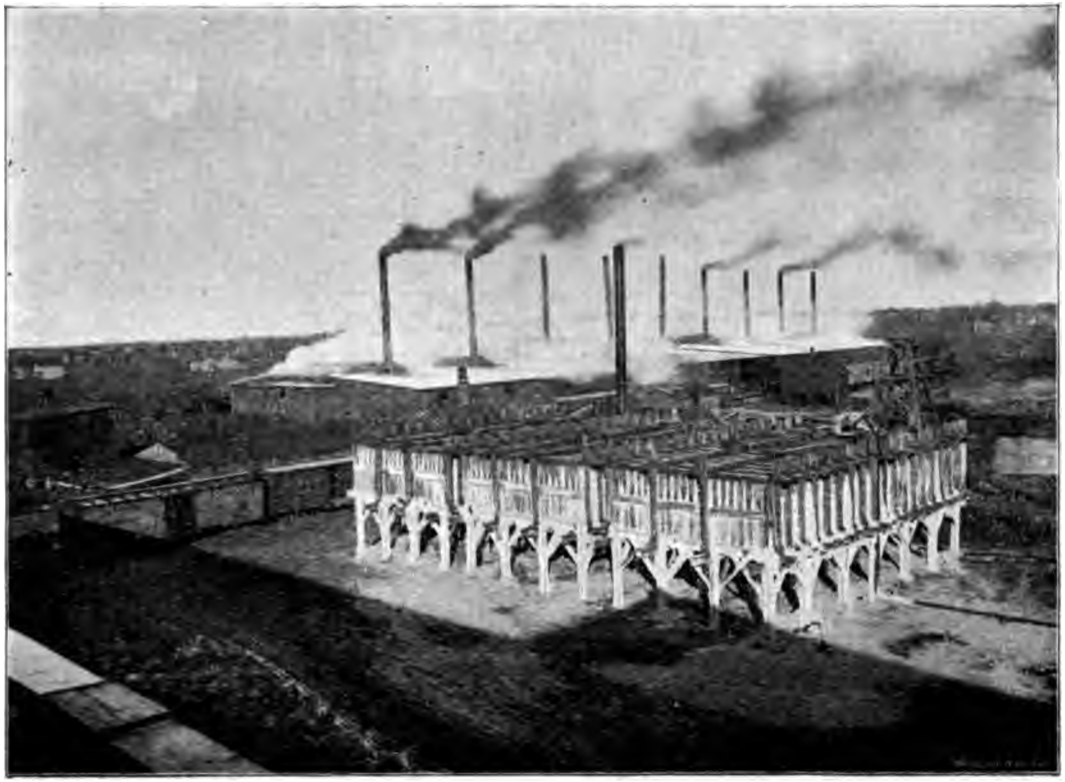
The Solar Process.

In the solar process the brine is obtained from a well about 100 feet deep, although the chief supply enters the well at a depth of only thirty-five feet.

From "Mineral Resources of Kansas for 1898," we quote the following:

"In making the salt, the brine is pumped from a well by means of a two-and-one-half-inch centrifugal steam-pump, having a capacity of 600 gallons per minute. It is delivered into a reservoir, where it becomes considerably concentrated by evaporation. The sediment pumped from the well subsides, and is shoveled from the bottom of the reservoir from time to time as occasion requires. To effect such a cleaning the pump is stopped, the brine turned into other rooms, the sediment shoveled out, and the reservoir properly cleaned with water. The depth of the brine kept in the reservoir is usually less than twelve inches, but considerable variation is noted from day to day, depending upon the rapidity of evaporation and rapidity of pumping.

"From the reservoir the brine is first carried into the 'water room,' where it is rarely allowed to be more than twelve inches deep. Here, the remainder of the mechanically held impurities subside, leaving an entirely clear brine to be passed on to the 'lime room.' In this second room the evaporation is carried far enough to cause precipitation of the principal im-



Hutchinson Salt Plant (general view).

purities held in solution, such as calcium carbonate, calcium sulfate, etc. After sufficient concentration in this room, the brine is next conveyed into the 'pickle room,' or the third one of the smaller rooms. It is left in the 'pickle room' until the concentration becomes so great that salt crystals begin forming. It is then transferred into the last or 'crystal room,' and allowed to remain until concentration causes the precipitation of nearly all the salt.

"By the solar process the evaporation is very gradual. The salt crystals begin forming first on the surface of the brine. If the brine is not agitated too much by the wind, the crystals frequently reach a large size; that is, from one-half to three-fourths of an inch on one side of the cube. This is particularly true where some slender object of support, such as a cord, or splinter from the wall of the vat, or a coarse piece of any kind of material is placed in the brine. Frequently, also, the well-known 'hopper-shaped' crystals are produced instead of the solid cubes.

"After a good bed of salt has been deposited in the 'crystal room' it is lifted into large baskets and allowed to drain for a few minutes, after which it is emptied into a horse-car, hauled to the storerooms, and allowed to 'cure,' or thoroughly dry."

At these particular works the brine is sometimes strengthened by adding to it crushed rock salt from some of the Kansas mines. This mixture is said not to yield so good a product as that made from the native brine. The brine, as taken from one of the vats, has been, perhaps, slightly concentrated. It has the following composition:

	Brine.	Salt.	Salt.
Sodium chlorid	120.08	98.20	98.53
Insoluble residue	.03	.08	......
Calcium sulfate	6.92	1.24	.92
Magnesian sulfate	Trace	.48	......
Sodium sulfate	5.89	......	.41
Magnesium chlorid	......	......	.14
Water	867.08	......	......
	1000.00	100.00	100.00

(Specific gravity at 72° F., 1.085 = B° 12.)

The Hutchinson Packing Company's Salt Plant.

MANUFACTURE OF SALT BY DIRECT HEAT.

Most of the salt put upon the market from Kansas is made by evaporation of the brine by direct heat. After the well has been bored it is cased with an iron pipe about five and five-eighths inches in diameter. Inside of this is a smaller pipe which is of sufficient size to allow water to pass between it and the larger pipe. The water that is forced down dissolves the salt, which is forced to the surface through the inner pipe, and is stored in convenient tanks till it can be evaporated. The brine is evaporated either by the "pan process," "grainer process," or by the "vacuum process."

THE PAN PROCESS.

In the pan process the brine is evaporated by direct heat. The pan consists of a wrought-iron vessel about 125x25 feet and about 12 inches deep. A coal fire (usually "slack" is used as fuel) is built beneath one end of this pan, and the products of combustion pass under the whole length of the pan. The brine is allowed to trickle into the pan in a slow but constant stream. The first division of the pan, and in some cases several divisions, are so arranged that the brine can be retained there till it had been evaporated sufficiently for it to deposit some of its impurities, especially the calcium sulfate. When this has been accomplished, the brine, which is now saturated with salt, is allowed to flow into the last division of the pan, where the heat is not so intense. Here the salt crystallizes out and falls to the bottom of the pan. It is removed from the pan by being scraped out by workmen with long-handled rakes upon the platform at the side of the tank, where it is left for some time to drain before being shoveled into carts for transfer to the storeroom. Here it stays for several weeks, or until it can be shipped, and it drains still more through the perforated floor provided for this purpose. Each pan is raked once in two hours. Although each pan and furnace form a complete set for making the salt, it is customary in the larger "blocks" to place a number of these pans side by side, and the product is then all dumped into a common storeroom.

As an illustration of the quality of the different brines the following analyses are given. The samples were taken directly from the storage tanks (analysis by E. H. S. Bailey and E. C. Case):

	Wellington.	Sterling.	Hutchinson.
NaCl (salt)	247.270	293.760	286.080
SiO_2	.030	.025	.075
$MgCl_2$	.684	.966	1.190
$CaSO_4$	5.464	5.185	5.404
$CaCl_2$	....	....	.320
Na_2SO_4	.028	.706	....
H_2O (by difference)	746.524	799.358	706.931
	1000.000	1000.000	1000.000

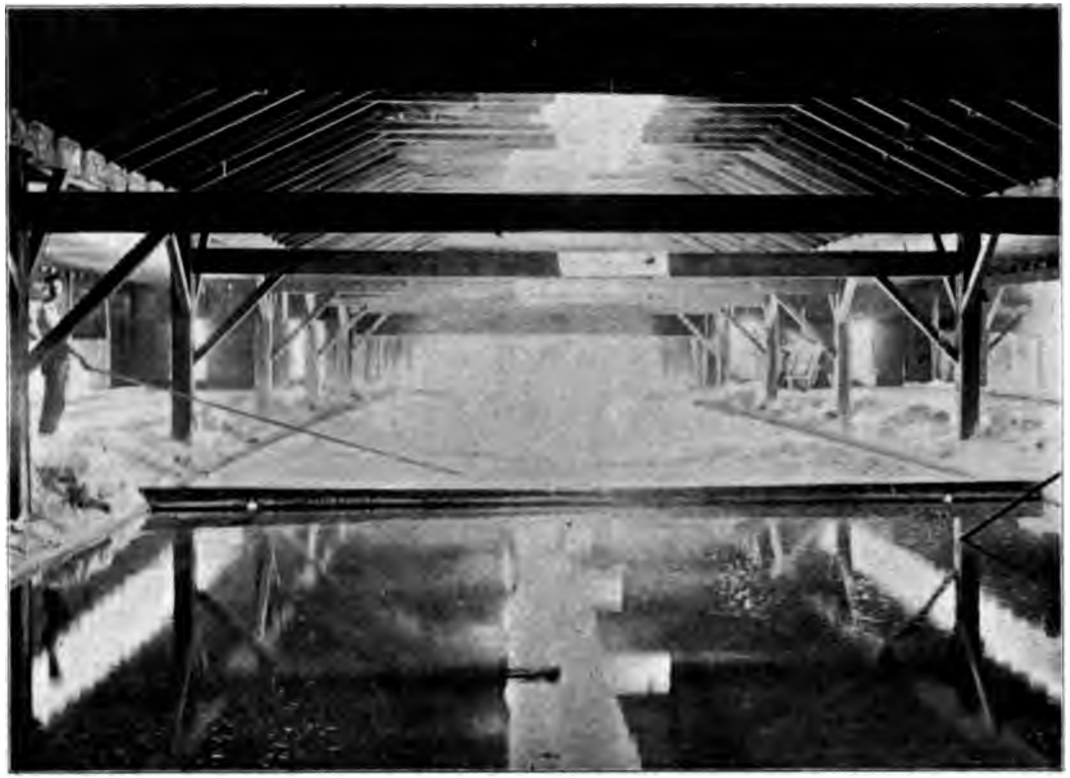
THE GRAINER PROCESS.

This is an American system, and was devised for the purpose of producing salt cheaply from comparatively weak brines. By combining the lumber and salt industries the manufacturers were able to utilize the exhaust steam from the sawmills during the day and use direct steam at night for evaporating the brines. In this process the brine is heated in the "settler" and then drawn off into the various evaporating pans, which are heated by steam-pipes running backwards and forwards across the bottom of the pans. The less soluble impurities, especially the gypsum, collect on the hottest part of the steam-pipes. This coating may be removed from time to time, after the mother-liquor has been drawn off, by turning steam into the pipes, thus causing them to expand so that the scales can be broken off.

The process of making salt is a continuous one. New brine is added, and the salt is raked out as often as necessary, and is deposited upon the platform at the side of the pan to drain.

A single example of a commercial brine and of the salt manufactured from it will suffice:

	1000 parts of brine.	Per cent. composition of salt.
Sodium chlorid	264.780	98.23
Insoluble residue	.050	.01
Calcium sulfate	6.009	1.68
Magnesium chlorid	1.200	.08
Calcium chlorid	.353	......
Iron oxid	.050	......
Water	727.558	......
Total	1000.000	100.00



Interior of a Hutchinson Salt Plant, Showing Evaporating Pans (end view.)

THE VACUUM PROCESS.

The third process for making evaporated salt is known as the "vacuum process." This process has not been extensively used, but the apparatus consists essentially of a kettle which is connected with a vacuum pump so that the brine may be boiled at a lower temperature. The salt that is formed is automatically carried away and fresh brine is at the same time supplied to the pan as rapidly as evaporation takes place.

KANSAS SALT COMPARED WITH OTHER BRANDS.

Some examples have been given to show the purity of the Kansas salt. The following analyses of other salts that are on the market are quoted for comparison :

Higgins's	97.8
Onondaga	97.7
Ashton's	97.6
Deckin's	97.5
Worthington	97.4

With abundant brine, and that of excellent quality, the only obstacle that can stand in the way of economical production of salt in large quantities is cheap fuel. By the use of coal-slack the cost of fuel has been considerably decreased ; but still, the expense is large compared with that in some other salt regions where slabs are burned or coal-mines are near at hand. By the use of more economically constructed furnaces much will no doubt be gained, for, by the present methods, much of the coal goes out through the chimney in unburned carbon, under the name of "smoke." This is all lost fuel, of course. Possibly, by some cheap system of compression, the vast quantity of straw and corn-stalks that are produced in the state may yet be utilized as fuel.

In studying economy of production, it will be noted, also, that only a saturated brine should be used for evaporation. Every pound of unnecessary water evaporated adds to the expense ; so the rate of pumping of the brine should be carefully watched.

There has been an increasing amount of salt produced in the state since 1888, when the industry began to be fairly established. The latest available report, that for 1899, shows a production of 2,172,000 barrels.

CHAPTER V.

THE THEORY OF SOLUTIONS.

BY PROF. H. P. CADY.

The modern theory of solutions is of especial interest in connection with a discussion of mineral waters, because of the light which it throws upon the condition and properties of the dissolved mineral matter.

Solutions Defined.—A solution may be defined as a homogenous mixture of two or more substances which resembles a chemical compound in that the constituents cannot be separated by ordinary mechanical means, but which differs from a chemical compound in that the relative proportions of the constituents may vary between wide limits. Solutions may be divided into two classes: First, solutions which will conduct electricity; second, solutions which will not conduct electricity. Solutions of the first class are of the most interest here because in this class are included solutions of acids, bases and salts in water, and hence it embraces all mineral waters which are simply aqueous solutions of various mixtures of the above-mentioned substances.

Theory of Ionization.—There are a good many reasons for believing that in solutions which will conduct electricity the molecules of the dissolved substances are broken up by the action of the solvent into smaller parts, called ions. This belief rests upon a great body of experimental facts which are too numerous and complex to be discussed here. According to this theory, when common salt, sodium chlorid, is dissolved in water, the molecules of sodium chlorid are broken up by the action of the solvent into sodium ions and chlorin ions, each of which is entirely free, uncombined, and independent of the others. These ions are not to be confused with the atoms of the elements, for

they differ from them markedly in properties; for instance, metallic sodium attacks water vigorously, the sodium ion does not; chlorin is a gas having a greenish-yellow color, disagreeable odor, etc., chlorin ion has none of these properties. This great difference is due to the fact that the ions are very heavily charged with electricity.

Action of Solvents.—Comparatively few solvents have this power of breaking up or dissociating dissolved substances, and of these water is the most powerful. But by no means all substances can be broken up into ions, even when dissolved in water; sugar, glycerol, alcohol, etc., are not dissociated to a perceptible degree, and their solutions do not conduct electricity.

Degree of Dissociation.—The degree of dissociation of an ionizable substance depends upon the concentration of the solution; the more dilute the latter is, the greater the degree of dissociation. In solutions as dilute as most mineral waters, the substances may be regarded as being completely dissociated, and therefore the properties of such mineral waters are simply the sum of the properties of the ions present.

Combination of Elements in Water Analysis.—The question of how to combine the results of an analysis of a mineral water has always been a vexed one. But with the modern view of solutions all these difficulties disappear, for most waters are so dilute that the substances are not combined but are present as ions; or if the solution is more concentrated, the same ions will be present, together with all the possible salts. For instance, if a dilute solution of sodium chlorid which will contain simply sodium ions and chlorin ions but not an appreciable quantity of the compound sodium chlorid, be mixed with a dilute solution of magnesium sulfate, which will contain simply magnesium ions and sulfate ions, there will be no reaction, and the solution will contain only these four ions and none of their possible compounds. Such a solution is absolutely identical in physical, chemical and therapeutic properties with one which is made by dissolving in the same quantity of water an equiva-

lent quantity of sodium sulfate and magnesium chlorid, and it would be impossible for any one to detect the least difference between the two solutions. If the solution is more concentrated so that the dissociation is not complete, there will be present the four ions—sodium, magnesium, chlorin, and sulfate, together with the four possible salts—sodium chlorid, sodium sulfate, magnesium chlorid, magnesium sulfate. Further, two of such solutions will be absolutely identical, no matter which pair of salts be dissolved. Under these circumstances, it would be obviously incorrect to report the substances as present either as sodium chlorid and magnesium sulfate, or as sodium sulfate and magnesium chlorid. The only rational way is to report them as ions, and this is the method that has been given prominence in this work, although the other methods have been followed also for comparison.

Therapeutic Properties Rest Largely in the Ions.—The therapeutic propeties of a mineral water are the sum of the properties of the ions, together with those of the undissociated portions of the salts present. Most mineral waters are so dilute that the undissociated portion of the salt may be neglected and the attention directed merely to the ions. The therapeutic properties of the various ions will be discussed in another portion of this work.

Occurrence of Ions in Mineral Waters.—It is of interest to notice that the following ions which are required by animals for their growth and nutrition are all present in mineral waters, namely: Na, Cl, CO_3, Ca, K, Mg, I, Fe, PO_4, and SO_4. Mineral salts are also carried by water to the rootlets of plants, and the following ions which are necessary to their growth are present in waters: K, Mg, PO_4, CO_3, with Ca, in most cases, and Mn often; NO_3 and SO_4 are useful as nutrients.

CHAPTER VI.

METHODS OF ANALYSIS, OF CALCULATION, AND OF STATING RESULTS.

METHODS OF ANALYSIS.

Total Solids.—This determination is made by evaporating from 100 cc. to 500 cc. of the water to dryness on a water-bath in a weighed platinum dish, and then heating the residue to 130° C. in the air-bath. The presence of various hygroscopic salts may cause this result to be more or less dependent on the quickness with which the weight is made. The result is of special use as a "control" test, so this determination is never neglected. It is sometimes advisable, after weighing, to ignite the dried residue, so as to notice if an appreciable blackening takes place. This blackening would indicate the presence of large quanties of organic matter.

Determination of Bases.—The analysis for those bases that are most abundant is made by using a fresh sample of water, from one to ten liters, dependent on the amount of total solids obtained above, acidulating it with hydrochloric acid, and evaporating to dryness on the water-bath. The evaporation may be hastened by boiling gently at first in a porcelain evaporating dish, and adding measured quantities of water from time to time, and completing the operation on the water-bath. The residue is either heated on the water-bath till every trace of odor of hydrochloric acid is gone, or it is heated to 110° C. on a water-bath for some time. After moistening the residue with hydrochloric acid and digesting, water is added, and the solution is filtered. It is of the utmost importance to note at this stage that in the presence of notable quantities of calcium sulfate, a single treatment in this way is not sufficient, but the residue should be boiled several times with dilute hydrochloric acid and water.

Silica and Insoluble Residue is the term applied to the above precipitate. After this is weighed, it may be tested for purity by heating with hydrofluoric acid. If any residue remains after this treatment, it should be tested for barium sulfate and other constituents by fusion with sodium carbonate.

For *Iron and Aluminum Oxids*, the filtrate from the silica and insoluble residue is treated by the ordinary methods, using ammonium chlorid and ammonium hydroxid. If the amount of this precipitate is considerable, the precipitate should be redissolved and again precipitated, using the same filter for collecting the precipitate the second time, and combining the filtrates. This precipitate, in addition to the above oxids, may contain phosphoric anhydrid, in case a qualitative examination has shown that to be present in the water. To determine the iron, after weighing, dissolve the precipitate in concentrated hydrochloric acid by digesting for some time, and determine the iron volumetrically in a sulfuric-acid solution by the ordinary methods. If phosphoric anhydrid was present, that should be determined in a separate sample of the water. The sum of this oxid and ferric oxid substracted from the total precipitate is calculated as alumina.

For the determination of *Calcium*, the filtrate from the iron and aluminum hydroxids should be treated with ammonium oxalate, and the solution should be kept warm for some time. In case much magnesium is supposed to be present, it is best to dissolve the precipitated calcium oxalate in hydrochloric acid and precipitate a second time, combining the filtrates. Calcium may be weighed as oxid or sulfate.

As *Magnesium* still remains in the filtrate from the calcium, evaporate this filtrate to dryness with an excess of nitric acid in a porcelain evaporating dish, and finally heat over wire gauze. By this treatment, in ordinary waters the ammonium salts will nearly all be converted into ammonium nitrate, which, at a higher temperature, is broken up into nitrous oxid and water, both of which are readily volatile. In this way the excess of ammonium salts, which would interfere with the complete precipitation of magnesium, is nearly all removed. The residue

is dissolved in water acidified with nitric acid, filtered if necessary, and treated with a few drops of ammonium chlorid, then with ammonium hydroxid and sodium hydrogen phosphate, by the ordinary methods.

For the determination of *Sulfuric Acid*, a fresh portion of the water, from 100 cc. to 1000 cc., is acidulated with hydrochloric acid, filtered if necessary, and evaporated somewhat, if the amount of sulfuric acid is small. The solution is heated to boiling and treated with as small a quantity of hot barium chlorid solution as possible to insure complete precipitation, and after standing for some time the precipitate of barium sulfate is filtered off. After weighing, as this precipitate is so liable to carry down with it other barium salts, it is boiled with hydrochloric acid, and, after the addition of water, filtered, ignited, and again weighed.

For the determination of *Potassium* and *Sodium*, the filtrate from barium sulfate is evaporated to dryness with hydrochloric acid, and silica is separated as usual. The solution is then treated with barium hydroxid, and, after standing for some time, is filtered. The filtrate is concentrated to small bulk and ammonium carbonate is added and the solution is again filtered. The filtrate is evaporated to dryness in a platinum vessel, and the residue is ignited at a low temperature. A few drops of water are added to the residue and a small piece of solid ammonium carbonate is added, and the solution is allowed to stand for a short time. In case a precipitate, which would be carbonates of alkaline earths, is obtained, filter off, and evaporate the filtrate to dryness and again heat cautiously, and weigh. The residue consists of chlorids of the alkalies, and may be examined for the individual alkalies by well-known processes. If lithium has been found by a spectroscopic test, a larger quantity of water must be used and a special determination of lithium made.

For the determination of *Sodium Carbonate*, a liter of the water is evaporated on a water-bath to dryness, distilled water is added, and the solution is filtered, with slight washing of the

precipitate. The filtrate contains the sodium carbonate, which may be estimated by the ordinary alkalimetric methods.

The amount to be used for the estimation of *Chlorin* depends upon the quantity of chlorids in the water. For ordinary waters from 200 cc. to 500 cc. is sufficient, and, in the latter case, it is advisable to concentrate the water by boiling, first making the water exactly neutral by sodium carbonate, in case it has an acid reaction. Determine the chlorin by titration with a standard solution of silver nitrate, observing that the water should be made exactly neutral before titration.

In the estimation of *Lithium*, the method suggested by Gooch was followed.[32] To the concentrated solution of the weighed chlorids of sodium, potassium and lithium amyl alcohol was added, and heat applied gradually, until steady boiling was effected (about 270° F.) This precipitates the potassium and sodium chlorids, and dissolves the lithium chlorid. To the cooled liquid two drops of strong hydrochloric acid were then added, and the boiling repeated. The solution was allowed to settle, and decanted through a filter, and the filtrate measured. The residue was washed with dehydrated amyl alcohol, and the washings added to the filtrate after measurement of the former. The filtrate and washings were evaporated in a platinum crucible to dryness, converted to sulphate, heated to fusion, cooled, and weighed. From this weight was subtracted for each ten cubic centimeters of the filtrate .0005, .0006 or .0010 grams, according as only sodium chlorid, potassium chlorid, or both, were present in the amyl alcohol filtrate. The presence of lithium in the sulfate residue was in each case confirmed by the spectroscope. Special evaporations of at least a liter of the waters were made for the lithium determinations.

For the determination of *Barium* and *Strontium*, the following method has been found to be very satisfactory: [33]

"Evaporate from five to fifteen liters of the water nearly to dryness, filter, and wash. The residue will contain barium and strontium as carbonates and sulfates, and the filtrate may be

32. See Leffmann and Beam's "Examination of Water for Sanitary and Technical Purposes."
33. Condensed from Cairns's Quantitative Analysis, pages 296-298.

used for the determination of bromin, iodin, and boric acid. The residue is treated with hydrochloric acid, evaporated to dryness, as in the separation of silica, and the insoluble residue is filtered off. Call this filtrate 'solution B.' The residue last mentioned is heated with hydrofluoric acid to expel silica, and then fused with sodium carbonate. The fused mass is dissolved in water, and the precipitate, which would contain the barium and strontium as carbonates, is dissolved in hydrochloric acid and added to solution B. This solution, with solution B, is treated with sulfuric acid to precipitate the sulfates of barium and strontium, the precipitate is ignited and fused with sodium carbonate, digested with water, and filtered. The insoluble part is treated with acetic acid, and in this solution the barium is precipitated with potassium chromate. This precipitate, after being filtered off, is digested with sulfuric acid, and finally weighed as *barium sulfate*. The filtrate from the barium chromate is digested with ammonium carbonate, and the strontium carbonate, with a little calcium carbonate, is filtered off. This precipitate is dissolved in nitric acid and evaporated to dryness in a weighed platinum dish. The solid residue thus obtained is digested with a mixture of equal parts of absolute alcohol and ether, which will dissolve the calcium nitrate without having any appreciable action on the strontium nitrate. Weigh the residue as *strontium nitrate* in the platinum dish. Test all the residues with the spectroscope."

For the determination of *Boric Acid*, an excellent method is that suggested by Gooch.[34] In this process the dried salts are treated in a retort of special construction, which can be heated in a parafine bath, with acetic acid and methyl alcohol, and the latter on being distilled off carries with it the boric acid. This acid is then caught in a known weight of calcium hydrate, and after the operation the calcium oxide is heated and determined. The increase in weight of the lime is due to the boric anhydrid (B_2O_3) that has been absorbed.

For the determination of *Fluorin*,[35] a large quantity of the

34. Am. Chem., Jour., IX, 23; also, Cairns's Quant. Anal., p. 299.
35. Cairns's Quant. Anal., p. 301.

water is concentrated, and precipitated with calcium chlorid, and after filtration the ignited precipitate is treated with acetic acid to dissolve the carbonates. The residue which contains the fluorids is dried, and mixed with pulverized quartz and concentrated sulfuric acid, and heated. The loss in weight is the hydrofluric acid which has been volatilized.

In order to determine *Sulfur*,[36] which may be present as sulfids, hyposulfites, or free hydrogen sulfid, the water must be treated at the springs for each of the ions supposed to be present. The sulfur existing as free hydrogen sulfid gas and as sulfids may be determined by treating a known volume of the water at the spring with an acid solution of cadmium clorid, and, after filtration, determining the cadmium by the usual methods.

For the quantitative determination of *Chlorin*, *Bromin*, and *Iodin*,[37] the mixture of the evaporated salts is placed in a flask of 250 cc. capacity with 40 grams of potassium dichromate and enough water to make 100 cc., counting the water in which the halogens were dissolved. The flask is provided with a dropping funnel through which water may be added to keep the volume of the solution above two-thirds and not more than the original amount. The flask is also connected to a vertical condenser, which condenses the steam and halogen vapors. The halogen vapors are received at the lower end of the condenser in a five-per-cent. solution of potassium iodid. After the mixture has been boiled till the iodin is all distilled, eight cc. of sulfuric acid (equal volumes of sulfuric acid and water) is added through the dropping funnel, and the mixture is again distilled until bromin no longer comes over. The iodin distilled over and the iodin set free by the bromin which was distilled over are each titrated with $\frac{N}{100}$ thiosulfate solution, and the iodin and bromin calculated from the amount used. The chlorin can be estimated with a silver nitrate solution in the cooled residue in the flask.

For *Nitrates*, the methods described in the report of the Massachusetts Board of Health for 1890 may be employed.

36. Erdmann's Journal, vol. LXX, or Cairns's Quant. Anal., pp. 302-304.
37. Journal of the British Chemical Society, vol. 49, p. 682, M. Dechan.

METHODS OF CALCULATION AND OF STATING RESULTS.

It is important to inquire what is the simplest method of stating results in a chemical analysis. We determine so much silica, calcium, oxid, sulfuric anhydrid, chlorin, etc.; so it has seemed to the author best to use what he has termed "radicals"; but even here, if he includes sodium oxid, there is an assumption that this is really the condition in which sodium should be combined. On this account, therefore, if we would state the exact result of the analysis, we can only do so in terms of ions (see chapter V), following practically the report of the committee of the A. A. A. S.,[38] appointed at the Buffalo meeting.

Ions and Radicals.—In stating the results, then, the ions are first reported, then the radicals, calculated from these ions; next, the probable combinations of the basic and acid ions, all in grams per liter; and finally the probable combinations, in grains per gallon. The method of expression by radicals will enable the chemist to better report the relative amounts of each substance found, while, if he wishes to report the actual elements determined, he can find them in the column marked "ions." It is true, in writing the radicals, we have included carbonic anhydrid and water, with the understanding, however, that these are usually "calculated," and not determined.

Now it practically happens that there is considerably more carbon dioxid than is necessary to combine with the bases with which we assume the combination takes place. This is of course due to the well-known solubility of carbonic anhydrid in cold water. In making the list of radicals, we have assumed, as above noted, that a certain amount of oxygen was united with the metals giving us Na_2O, K_2O, etc.; but we know, in comparing the sum of the individual constituents with the total solid residue, that often a part at least of the sodium was combined with chlorin, for instance, so that the oxygen of these radicals does not really belong there, and should be subtracted. It is true we have made arbitrary comparisons, as some one has said, which cannot be proved. Nevertheless, for convenience of comparison, this method is adopted.

38. J. Anal. Chemistry, vol. III, p. 398.

Hypothetical Combination.—As it has been the custom among water analysts to report the constituents as being present in definite combination as salts, the "hypothetical combination" has been stated in another column, so as to make the analysis more intelligible to the ordinary reader and to the physician who is not familiar with ions or radicals. This is especially desirable because we can thus compare the analysis of those waters with the analyses of other chemists. The problem in regard to what combination should be made is a complex one, for certain combinations that would take place in a dilute solution do not take place in a concentrated one. If the solutions of two salts are mixed, and an insoluble salt is precipitated by this mixture, then the reaction is a simple one. But how shall we know what takes place when, for instance, solutions of magnesium sulfate and sodium chlorid are mixed? No precipitate is formed. Does the solution contain each salt as originally present, or does a metathetical reaction take place, forming sodium sulfate and magnesium chlorid?

So many factors must be considered in the discussion of this question that we must decline to answer it positively. We must know the effect of temperature, of concentration, and of other salts in solution, as well as of the relative quantities of each salt present, before we can form a judicial opinion as to what combinations are actually present. If the solutions are dilute no change takes place, and the substances remain as ions. If the solutions are concentrated, all possible salts as well as all the ions will be present. (For a further discussion of this problem in the light of the most modern theories, see chapter V.)

Following the example of most chemists, the results are expressed in terms of grams per liter. This seems to be preferable in the case of mineral waters where the amount of total solids is large, rather than expressing the results in terms of parts per hundred thousand or parts per million, according to the custom in reporting the sanitary analysis of waters. We assume, of course, that grams per liter represents parts per thousand by weight, but this is only true in the case of waters having a very low specific gravity, and to make it absolutely true

in regard to all waters examined we must know the actual specific gravity, and take that specific gravity into consideration in making our calculations. We have adopted the system of expressing the results in grams per liter, also, looking hopefully to the time when this nation will follow other civilized nations and adopt the metric system as the only legal system of weights and measures.

Grains in a Gallon.—It unfortunately happens that in this country people have adopted the habit of representing the composition of mineral waters in terms of grains per gallon. The physician and the ordinary reader who is interested in sanitary matters have become accustomed to this, and they find difficulty in interpreting the results stated in any other way. Therefore, in deference to this fact, results are also expressed in grains per United States gallon of 231 cubic inches, as represented in the last column.

There is, however, unfortunately still a disagreement as to the actual relation of grains per gallon to grams per liter. It is hoped that this disagreement among authorities will be speedily reconciled. As an example of what some of the best authorities have used as a factor to express this relation, it is noticed that Professor Mason has used the factor 58.3349, Professor Chandler 58.318, Dr. A. C. Peale, of the United States Geological Survey, prefers 58.41, Prof. W. R. Nichols has used 58.37, Prof. Paul Schweitzer in his late report[39] recommends 58.41, and Professor Brockett uses the factor 58.372.

In the calculations in this volume the factor 58.41 has been employed.

39. Mo. Geol. Surv., vol. III, Mineral Waters.

Table of Factors Used in Water-analysis Calculations.

BY D. F. MACFARLAND.

Multiply the amount found by the factor to obtain the amount sought of the corresponding substance. Whole numbers, except 35.4 for chlorin, are used for atomic weights.

Found.	Sought.	Factor.
	CALCIUM.	
$CaSO_4$	CaO	.41181
	Ca	.29428
	SO_3	.58819
$CaH_2(CO_3)_2$	CaO	.34569
	H_2O	.11111
	$2CO_2$	.54321
	Ca	.2471
$CaCO_3$	$CaH_2(CO_3)_2$	1.6200
	Ca	.40032
	CaO	.56021
	CO_2	.43979
$CaCl_2$	CaO	.5050
	$2Cl$	.6389
	Ca	.5051
CaO	Ca	.71459
$Ca_3(PO_4)_2$	$3Ca$	.3910
	MAGNESIUM.	
$MgSO_4$	MgO	.3333
	Mg	.2000
$MgH_2(CO_3)_2$	MgO	.2739
	Mg	.1642
	H_2O	.1233
	$2CO_2$	.6027
$MgCO_3$	$MgH_2(CO_3)_2$	1.7380
	Mg	.2856
	MgO	.4769
	CO_2	.5241
$MgCl_2$	MgO	.4219
	Mg	.2530
	$2Cl$	.7468
MgO	Mg	.6000
	SODIUM.	
Na_2SO_4	Na_2O	.43682
	$2Na$	.32429
$2NaHCO_3$	Na_2O	.36910
	$2Na$	.2738
	H_2O	.10714
	$2CO_2$	.52380
Na_2CO_3	$2NaHCO_3$	1.5849
	$2Na$	.4347
$2NaCl$	Na_2O	.53083
	$2Na$	.39407
	$2Cl$	.60616
$Na_2B_4O_7$	Na_2O	.3070
	$2Na$	.2278
	B_4O_6	.6925
	B_4O_7	.7725
$2NaNO_3$	Na_2O	.3572
	N_2O_5	.6352
$2NaBr$	Na_2O	.3012
	$2Br$	.7760
$2NaI$	Na_2O	.2080
	$2I$	.8460
	AMMONIUM.	
$(NH_4)_2SO_4$	$2NH_4$	.2730

Found.	Sought.	Factor.
	IRON.	
$FeH_2(CO_3)_2$	FeO	.4045
	Fe	.3146
	H_2O	.1011
	$2CO_2$	.4943
$FeCO_3$	$FeH_2(CO_3)_2$	1.5345
	Fe	.4868
	FeO	.6201
	CO_2	.3790
Fe_2O_3	$2FeO$	.90002
	$2Fe$	.70008
	$2FeH_2(CO_3)_2$	2.2250
FeO	Fe	.7777
$FeSO_4$	FeO	.4740
	ALUMINUM.	
Al_2O_3	$2Al$	.5300
	MANGANESE.	
$MnH_2(CO_3)_2$	MnO	.4012
	H_2O	.1017
	$2CO_2$	.4970
	Mn	.3102
Mn_3O_4	$3MnO$	.9300
	POTASSIUM.	
K_2SO_4	K_2O	.54061
	$2K$	.44800
$2KHCO_3$	K_2O	.4800
	H_2O	.0810
	$2CO_2$	.4400
	$2K$	.3920
$2KCl$	K_2O	.63189
	$2K$	.5240
	$2Cl$	.4780
K_2CO_3	$2KHCO_3$	1.4492
	$2K$	.5652
K_2O	$2K$	.8299
	LITHIUM.	
$2LiCl_2$	Li_2O	.3540
	$2Li$	.0900
	$2Cl$	.8350
$2LiHCO_3$	Li_2O	.2206
	$2Li$	.1028
	H_2O	.1323
	$2CO_2$	.6471
Li_2CO_3	$2LiHCO_3$	1.8378
	$2Li$	.1891
Li_2O	$2Li$	.4670
	ACIDS, RADICALS, AND IONS.	
SO_3	SO_4	1.2000
SiO_2	SiO_3	1.2666
B_4O_6	B_4O_7	1.1142
$2PO_4$	P_2O_5	.7470
Oxygen equivalent of	Chlorin,	.22599
	Bromin,	.10000
	Iodin,	.06300

Some of the analyses reported in this volume are by other chemists than those of the Survey, and no definite figures are obtainable as to their methods of calculation. Where they have represented the hypothetical combination, as is usually the case, in terms of grains per gallon, from these figures the grams per liter, using the factor 58.31, have been calculated. The radicals have not usually been calculated in such cases. In several analyses the chemists have made no attempt at even a hypothetical combination, and here only radicals and ions per liter are given.

CHAPTER VII.

CLASSIFICATION OF MINERAL WATERS.

On account of the complex character of the material, and the fact that while one substance may be present in large quantities the character of the water is greatly modified by other substances which are present in smaller quantity, it is extremely difficult to classify mineral waters. The following systems of classification are common:

The French method:

Salt	Sulfur.
Bicarbonates	Ferruginous.
Sulfated	Indifferent.

The German method:

Alkaline	Epsom salt.
Earthy	Sulfur.
Common salt	Iron.
Glauber's salt	Indifferent.

The English and American methods are somewhat more complex. Doctor Buck[40] suggests the following:

Neutral springs, containing chlorides and sulfids.
Alkaline springs, containing carbonates.
Acid springs.
Those having special constituents, such as arsenic, alum, etc.

Under the first we have two subclasses, the chlorids and sulfates. There may be a large excess of one or of the other.

The bromids and sulfids are also included in this class. The Kreutznach water is an example of this class containing chlorids, and the Crab Orchard water and Friedrichshall water are good examples of sulfate springs.

Under the second class he would include alkaline and neutral salts such as carbonates of sodium, potassium, lithium and magnesium. The Saratoga waters are good examples of this class. Some changes are liable to take place in these springs

40. Reference Hand-book of Medical Sciences, volume IV, pages 690–694.

so that their composition may be different after a time. The change might be as follows: $Na_2CO_3+CaCl_2=CaCO_3+2NaCl$. This change was noticed in the case of the Harrowgate (Eng.) waters, which, after several years, were found to be saline rather than alkaline in character.

In the third class Doctor Buck would include sulfuric acid only. He admits that such springs are rare. The Oak Orchard springs (N. Y.) contain 13.37 grains of sulfuric acid to the pint, and the Rockbridge Alum (Va.) springs contain 2.34 grains.

In the fourth class he would include those like the Rockbridge Alum, containing 3.01 grains alumina out of 5.80 solids per pint. There are some arsenical springs in France that contain .1 of a grain of white arsenic per pint. The Dentonian well, Ballston (N. Y.) has .95 grains arsenic per pint.

The classification suggested by Walton[41] is as follows:

I. Alkaline waters	1. Pure. 2. Acidulous (carbonic acid.) 3. Muriated (chlorid of sodium.)
II. Saline waters: (Chlorid of sodium.)	1. Pure. 2. Alkaline. 3. Iodo-bromated.
III. Sulfur waters	1. Alkaline. 2. Saline (chlorid of sodium.) 3. Calcic.
IV. Chalybeate waters	1. Pure. 2. Alkaline. 3. Saline (sodium chlorid.) 4. Calcic. 5. Aluminous.
V. Purgative waters	1. Epsom salts (sulfate of magnesia.) 2. Glauber's salts (sulfate of soda.) 3. Alkaline.
VI. Calcic waters	1. Limestone (carbonate of lime.) 2. Gypsum (sulfate of lime.)
VII. Thermal waters	1. Pure. 2. Alkaline. 3. Saline (chlorid of sodium.) 4. Sulfur. 5. Calcic.

41. Mineral Springs of the United States and Canada.

Doctor Winslow Anderson[41] gives the following classification :

I. Acid mineral springs.
II. Alkaline mineral springs.
III. Alum mineral springs.
IV. Arsenical mineral springs.
V. Borax.
VI. Bromin.
VII. Calcareous, or earthy.
VIII. Carbonated.
IX. Chalybeate.
X. Chlorinated.
XI. Iodin.
XII. Magnesian.
XIII. Siliceous.
XIV. Sulfurous (Sulfureted.)
(Thermal.)

Prof. Schweitzer's classification.[42]

I. Muriatic. NaCl	1. + also $CaCl_2$, $MgCl_2$, $CaSO_4$. 2. + $MgCl_2$, $CaSO_4$. 3. + $MgSO_4$, $CaSO_4$.
II. Alkaline. Na_2CO_3	1. + or − $MgCO_3$. 2. $MgCO_3$ only.
III. Sulfatic	1. Na_2SO_4. 2. $MgSO_4$. 3. $FeSO_4$, $Fc_2(SO_4)_3$, Al_2 (sub.) $(SO_4)_3$.
IV. Chalybeate Waters	1. + $MgCO_3$, Na_2CO_3. 2. + $MgCO_3$, $MgSO_4$. 3. + $MgCO_3$, $MgSO_4$, $CaSO_4$.
V. Sulfur Waters	1. Sulfids only. 2. Sulfids and sulfhydrates. 3. H_2S, sulfids + thio-compounds.

Dr. Crook's classification (based on A. C. Peales's) :

I. Alkaline	Sulfated. Muriated.
II. Alkaline-saline	Sulfated. Muriated.
III. Saline	Sulfated. Muriated.
IV. Chalybeate	Alkaline. Sulfated. Muriated.
V. Neutral or indifferent.	

The following simple grouping, based upon the predominant ions present, is suggested and followed in this work :

I. Chlorid group, or those in which the chlorin ion (Cl) is the predominant one.

II. Sulfate group, or that in which there is a predominance of the sulfate ion.

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41. Mineral Springs and Health Resorts of California, pp. 21-38.
42. Geological Survey of Missouri, vol. III, Report on Mineral Waters, pp. 23-25.

III. The chlor-sulfate group, or waters which contain about equal amounts of the sulphate and the chlorin ion.

IV. The carbonate group, or those in which the carbonate ions (CO_3) are abundant.

V. The chlor-sulfo-carbonate group, or those containing considerable quantities of each of these ions.

VI. The sulfid group, or those waters that give off hydrogen sulfid, and are commonly called sulfur waters.

VII. The chalybeate or iron group. (This may also contain the few manganese waters.)

VIII. The special group, or those waters containing some special substance, like lithium, borax, etc.

IX. The soft water group, or those waters that contain only small quantities of any mineral substances.

CHAPTER VIII.

PROSPECTING AND BORING FOR MINERAL WATERS.

BY W. R. CRANE.

PROSPECTING.

Prospecting for water strata resembles more closely the search for horizontal bedded mineral deposits and oil and gas horizons than for irregular and highly inclined bedded and veined deposits and mineralizations.

As a rule, a water-bearing horizon, such as a sandstone stratum, when once reached and pierced by a bore hole, draws to and feeds such an outlet until the supply has been exhausted, or, if the supply is inexhaustible and the hydraulic pressure is sufficient to hold and maintain a certain head in the pipe, it may, as in the case of an artesian well, even eject water to a considerable distance above the surface end of the outlet or pipe.

A water well, artesian or otherwise, then, has about the same earmarks as an oil well, when considered from the standpoint of prospecting and boring, although, as water is much more abundant than oil, we should reasonably expect to experience much less difficulty in prospecting for the former. Then, too, in the subsequent operations of control and distribution a water well presents less serious and more readily solved problems. The intimate relation existing between gas and oil, as well as the comparative scarcity and therefore greater value of the same, is the main cause of the difference.

It is common practice to seek low ground for the site of a well. For shallow wells, those which pass into or just through superficial deposits and accumulations, the reason is evident. Any other location would sacrifice the quantity of water obtained to convenience.

When the deep-seated waters are sought, the location simply

means more or less depth of formation to penetrate, and a consequent higher or lower initial cost of the well—the question of quantity and quality of water being entirely independent of the same.

The location of a well for deep-seated waters will depend largely upon whether the artesian principle is desired or not. In such cases, synclinal basins and long stretches of country of moderate dip will furnish abundant hydraulic waters. In any case, especially in deep wells, hydraulic water is always desirable, as it means just so many foot-pounds less of water to be raised by pump. It is, therefore, always desirable to take advantage of any natural conditions which may exist in locating the site of a well.

It is permissible to use all the information at hand that can be gathered, such as geological maps and sections, records of deep wells in the neighborhood, and, when possible, natural and artificial cuts. The later may only show the depth of superficial layers, but this may in itself be highly instructive.

The probable quality and quantity of the waters that may be found are largely determinable from geological records, and, in fact, too great stress cannot be placed upon such sources of information.

The effect of the formation upon the quality of the waters found therein can be readily illustrated by examining the geological map of the state. (Plate I.) The eastern part of the state is made up of Lower and Upper Carboniferous strata, deposited in salt water—brines are the rule. Passing to the westward, on the south and to a limited extent on the north, the effect of gypsum is distinctly felt; while to the westward on the north the waters occuring in the Cretaceous area are highly charged with lime, which is also true of the waters existing in the calcareous sand-beds of the Tertiary formations.

Knowing then the geological relation of strata, together with the relative dip and thickness, it is by no means difficult to determine the quality of the water that may be found.

Regarding the quantity, the relative extent and lay of the

porous beds, together with the amount of rainfall in the district in which they outcrop, will give us sufficient data for calculation.

In the case of prospecting for water, the opening made is employed in extracting the water, *i. e.*, the prospect hole is a finished well.

DRILLS AND DRILLING.

Drills.—Prospecting and drilling are accomplished by means of drills, of which there are three kinds, namely: The churn, the diamond, and the calyx.

The *Churn* drill is a modification of the rod method of drilling largely employed in Europe. As used at the present time, in the United States, it goes by the name of the *oil-well* or *cable-tool* system. Of the class there are a large number of forms, some self-contained, that is, mounted on trucks, being complete in themselves; while others have the derrick and power parts separate, constituting the so-called *carpenter's rig and engine.* (Plate VII.)

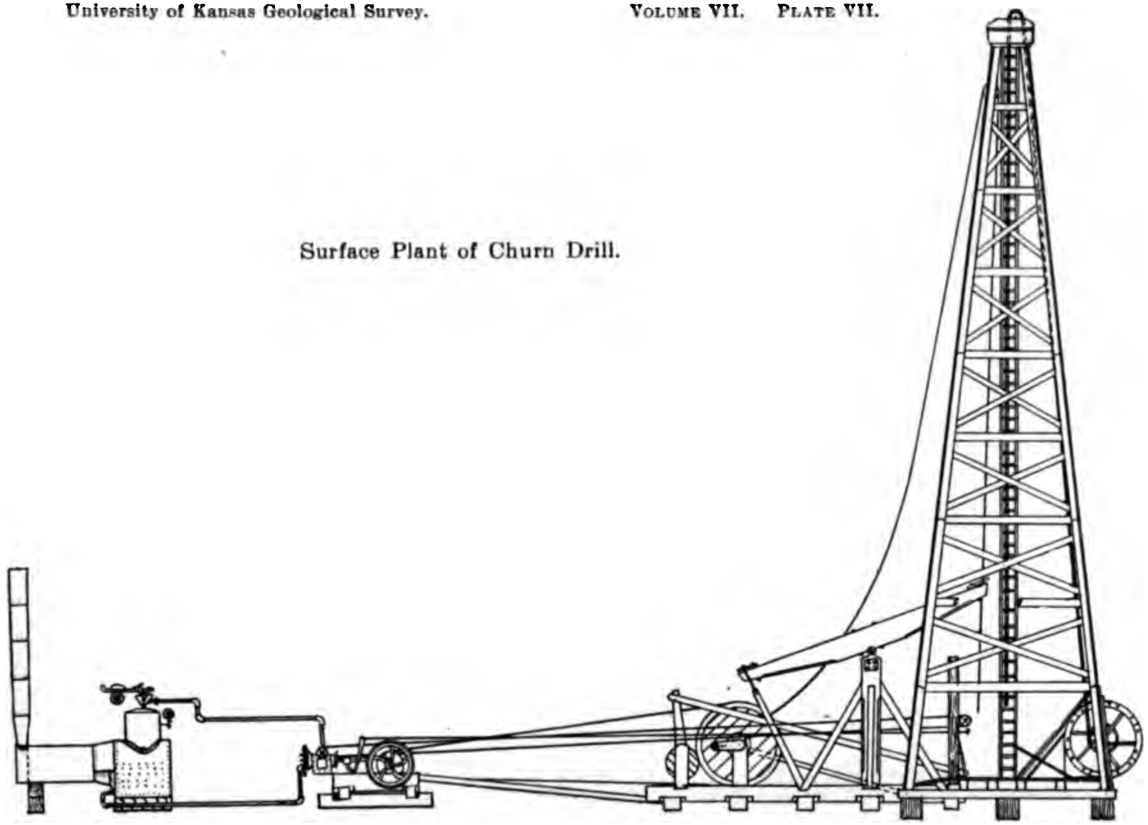
The *Diamond* drills have largely superseded the older methods of drilling in recent years, due to the ease and rapidity of drilling, and mainly on account of producing a complete record of strata passed through. (Plate VIII.)

The *Davis-Calyx* drill is a comparatively recent production, but has proven itself so efficient and has surmounted so many obstacles, which even precluded the use of the diamond drill, that it has come quickly into favor. (Plate IX.)

A complete record is also obtainable by this drill. The cutting is done, not by diamonds, but by steel teeth and chilled shot.

Description of the Churn Drills.—The apparatus for the oil-well or so-called churn drill consists of a derrick ranging from fifty to seventy-five feet in height, which is built up of heavy timbers, or better still of planks, so placed as to produce an angle-construction for the corner posts. The corner posts are given a batter of an inch or so to the foot, and are held in position by horizontal cross-girders, and are still further strength-

Surface Plant of Churn Drill.



ened by diagonal braces. The derrick supports two sheaves at the top, one for the drill and the other for the sand-pump rope.

Off to one side of the derrick, at a distance of sixty to seventy-five feet, is placed an engine, usually of the traction-engine type. From this engine a belt passes to a power- or drive-wheel, supported by a framework which also supports a reel employed in driving the sand-pump.

To the derrick base on a suitable support is hung the walking-beam, one end of which is connected by a pitman to the drive-wheel, while the other end is fastened to the rope, when drilling, by means of the temper-screw. On the opposite side of the derrick from the walking-beam is placed the bull-wheel, which is employed in raising and lowering the drill in the hole. When not in use, the sand-pump stands to one side within the derrick; when used, it is employed alternately with the drill—that is, after drilling for a certain length of time the drill is removed and the sand-pump lowered to remove the water and cuttings from the hole, and thus facilitate the drilling operations. It is operated by a friction-wheel working on the rim of the power-wheel, which can be thrown on or off at will.

The temper-screw consists of a split-nut fastened to the lower end of a steel frame, four feet six inches long, which is fastened to the walking-beam. In the split-nut a long steel screw operates. At the lower end of the frame is a clamp enclosing the split-nut, which, when tightened, forces the two parts of the nut together, making it in reality solid or like one piece. Screwing into the nut is a long, steel feed-screw, to the lower end of which is a ball-bearing swivel, linked to which is a clamp for holding the rope. A cross-brace is set-screwed to the feed-screw just above the swivel, by means of which the screw is fed through the nut, thereby lowering the drill in the hole, thus constituting the action of feeding. The object of the split-nut is to facilitate the setting back of the frame at the end of the feed; that is, by unclasping the split-nut the frame can be slipped down upon the feed-screw; otherwise it would have to be screwed back, which would necessitate considerable time and consequent delay.

The drill part proper consists of several separate parts, and goes by the name of the string, or line of tools, and is about sixty-five feet in length. Beginning with the bit end, the parts are as follows: Bit, auger-stem, jars, sinker-bar, and rope-socket. A rope extends from the rope-socket to the bull-wheel, by way of the top or head sheave. The bit has several forms, which differ in shape with the purpose for which they are intended and the formation to be worked. There are two general forms, known as the cutter-bit, and the reamer. The cutter-bit is chisel-shaped, while the reamer is H-shaped, and is used to straighten up the hole from time to time. The auger-stem is a section of rod screwed to the bit to give sufficient weight for cutting. The jars are made up of two links, which slide one upon the other, and are fastened to the sinker-bar and auger-stem above and below. The object of the jars is to loosen the bit if it gets caught in the hole. The links slide one upon the other for a certain distance, thus allowing the upper part of the line of tools to acquire sufficient momentum to pick up the bit. Their action is especially useful in fissured ground, where the bit is liable to be caught by jamming in a fissure. The sinker-bar is also a section of rod, like the auger-stem, the purpose of which is to keep the rope taut. To the top of the sinker-bar is screwed the rope-socket, in which is inserted the rope.

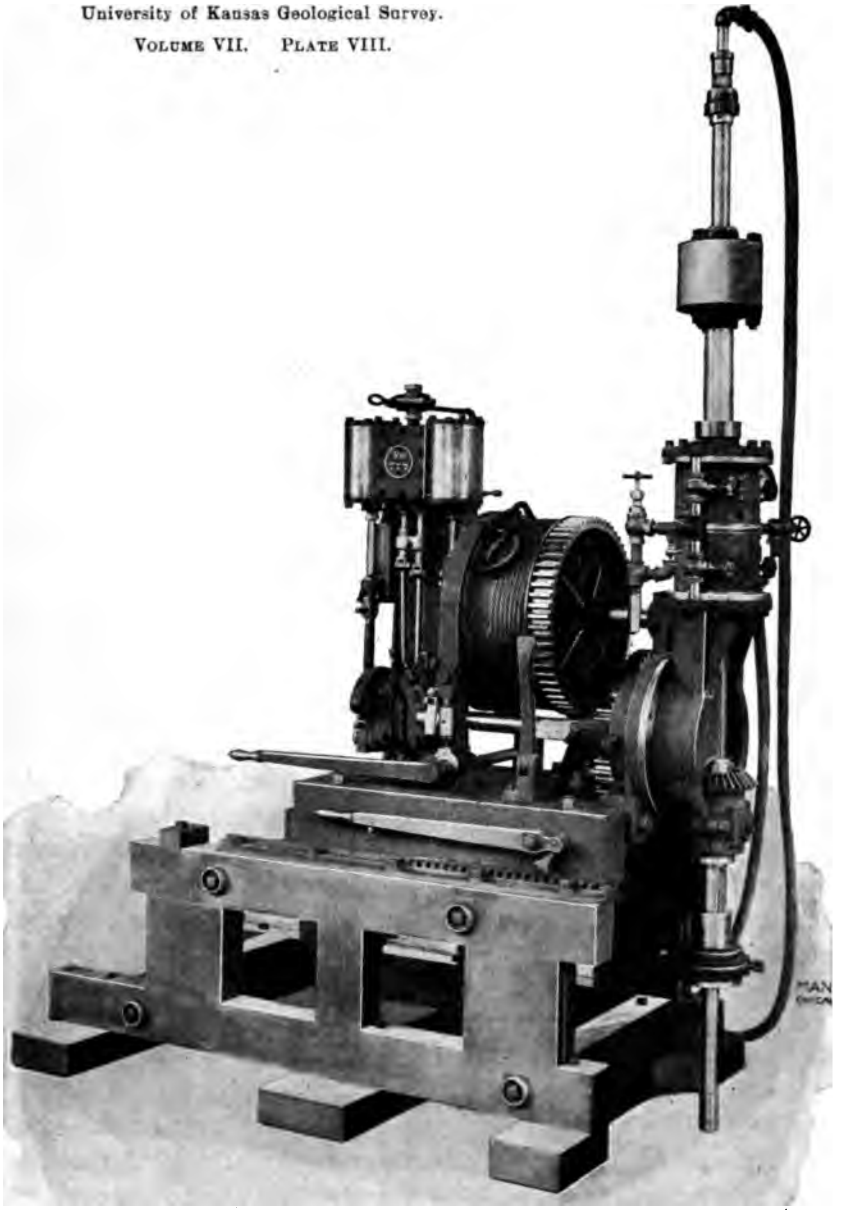
Method of Operation of Churn Drill.—When drilling begins the drill is lowered until the two parts of the jars meet; it is then raised until only four inches of clearance is left between links. The power-wheel is then turned until the pitman is at the top of the stroke; the walking-beam is then at the lowest part of its stroke. In this position the temper-screw is attached to the rope. From twenty to thirty feet of rope are then unwound by turning the bull-wheel, which loose rope is wound up in a large coil on the platform about the driller.

Starting up the engine causes the walking-beam to move up and down, thus transmitting to the drill through the rope a chopping or reciprocating motion. As the hole is deepened the bit must be lowered, which is accomplished by unscrewing the temper-screw. The action of feeding also tends to turn the line

of tools, through friction in the swivel, which is of positive advantage, as it keeps the hole round, but if it is continued in one direction to the end of the feed the rope will have become very much tangled. This is obviated by allowing the drill to turn while feeding for several revolutions, then reversing the direction of the turning of the swivel, at the same time feeding as before. By making the same number of turns first in one direction and then in the other, the rope is kept free of twist and tangle. The strokes of the walking-beam range from thirty to forty-five per minute. Shifts change at noon and midnight. The sand-pump is geared up so that it can be raised at a high speed, with a minimum loss of time. It is lowered by gravity.

It is customary, at the beginning of operations, to sink the first 50 or 100 feet of the hole by driving the casing as a drive-pipe and sand-pumping the material from the inside. In connection with the driving of the casing, the line of tools, without the jars, may be employed. It is raised and dropped, thus loosening up the material at the bottom of the hole and facilitating the driving of the casing. The walking-beam is not brought into use in this preliminary work, movement being given to the drill by a loop of rope passing over the crank upon the power-wheel and inclosing the drill rope, as it descends from the sheave above, at some distance above the bull-wheel. The bull-wheel, being held fast, causes the line of tools to rise as the rope is pulled from a straight line by the rotation of the power-wheel. The amount that the drill is raised will depend on the position of the crank upon the power-wheel; *i. e.*, whether the radius is long or short. The operation of sinking the hole, until the full length of the line of tools can be employed, is known as *spudding*. A record is obtained by preserving the cuttings raised by the sand-pump, and when care is taken a very complete log is possible.

Description of the Diamond Drill.—The diamond drill employed in deep-well boring is provided with a hydraulic feed, which consists of a cylinder through which passes the hollow drill-rod. Enclosing the drill-rod is the so-called drive-rod, which in turn is enclosed by the piston-rod. To one end of the



Diamond Drill, Hydraulic Feed.

piston-rod is attached the piston. The other end of the rod is fastened to the drive-head. The drive-head is provided with two sets of ball bearings, between which is a flanged collar securely fastened to the drive-rod. Any movement of the piston, caused by forcing water into one end of the cylinder and allowing it to escape from the other, will produce a similar movement in the drive-rod. Below the cylinder the drive-rod is provided with a clamp-head or chuck, by means of which it can be securely fastened to the drill-rod proper. Any movement of the piston will then be transmitted at once to the drill-rod.

The feed is extremely sensitive and easily regulated, as it depends entirely upon the amount of water that is fed to the cylinder. The cylinder is fed by a force-pump. The feed may be employed not only in forcing the drill downwards against the bottom of the hole but also in lifting the rod. The rod may also be lifted by cable, which winds upon the drum driven by the actuating mechanism of the drill, and passes over the sheave placed on the derrick top erected above the drill. The upper section of the rod is provided with a flexible ball-bearing jetting connection, by which, through a hose, water is brought to and forced down the rod to the bottom of the hole, thence rising upwards bears with it the cuttings and sludge produced by the action of the drill on the formation worked.

There is another method of feeding, namely, the "differential-screw feed," which is employed mainly on the smaller machines, such as are used for comparatively shallow holes and underground work.

The hydraulic feed is especially adapted to large-sized and deep wells. It is heavy and, therefore, less convenient to move, but, due to the ease and rapidity of change of the feed, it is growing in favor.

The rod is a strong iron or steel tube, with a small-sized hole to furnish free passage for the water to the bottom of the hole, and to allow a return current outside the rod and between the rod and the hole.

The essential parts of the drill proper are at the bottom or lower end of the rod, and are, in the order in which they occur,

from the bit up, as follows: The bit, the core-lifter, the core-barrel.

The bit is the part which contains the diamonds. The arrangement of the diamonds on the bit is quite varied, the main idea being to so place them as to cause their respective tracks or courses to lap, thus eveningly and uniformly wearing away the rock. It is common practice to provide grooves in the sides and edge of the bit to insure a more even flow of water for removing the cuttings from the bottom of the hole. The action of the diamond drill upon the rock is not cutting, but grinding—the diamonds being set so as to slide, and when forced down will drag out or grind a groove. The diamonds or stones used for drilling are borts (defective brilliants) and carbons (colored diamonds), and are obtained largely from South America.

Above the bit is the core-lifter, of which there are two general forms, namely: The *cossette* and the *split-ring*. The cossette form consists of a series of spines, which are attached at the lower end around the inside of the body of the lifter. The core in rising, or the drill in passing downward, raises them in a vertical position, but when the operation is reversed, the drill-rod and lifter being raised, they catch in the sides of the core and prevent its withdrawal. The split-ring core-lifter is, as the name indicates, a split-ring which encloses the core. The ring is tapering and rests in a tapering recess, which is an enlargement of the hole through the section of the rod which constitutes the body of the lifter. As the drill works its way downward the core rises through the core-lifter, pushing the split-ring in the upper and larger part of the tapering recess, thus allowing it to expand to its normal shape, and presenting practically no resistance to the passage of the core through it. When, however, the full length of the feed is reached, and it is desired to raise the core, the split-ring attached to the core is drawn downward into the narrowing recess by the raising of the drill-rod, and is consequently caused to tighten its grip on the core. To prevent slipping, the inner surface of the split-ring is provided with teeth, which point upward and inward.

These teeth will then set upon the core and hold it rigidly, allowing it to be broken off and raised to the surface.

Next in order above the core-lifter is the *core-barrel*, which consists of a hollow rod, with the opening sufficiently large to allow the entrance of the core, and is as long as it is desirable to have the feed, which may range from two to ten feet. Occasionally, when especially friable and soft strata are worked, to prevent the breaking off and consequent wearing away of the core, an inner core-barrel is inserted, which is provided with ball bearings at the top and bottom ends. Into this inner casing the core is pushed, and by means of light springs it is supported and partially protected from the wash-water, the greater part of which passes on the outside of the inner casing. By this means complete records are often obtainable, which would otherwise be partially destroyed, the exact amount worn away not being known.

Method of Operation of Diamond Drill.—The drill having been set up in the position desired, and a shallow opening or hole made, the proper length of the rod is added and lowered into the hole. Power is then turned on and the feeding begun; the full advance being made, the rod is raised and the core removed. This operation is repeated until the required depth is reached or reaming is necessary. After a certain advance has been made, another section of rod must be added. The character of the cuttings is noted and the cores are preserved, which will constitute the log of the well.

An increase or decrease of the water escaping from the hole furnishes important information as to the character of the water met. When hydraulic waters are met, it is quite often the case that no water need be fed to the rod, the hole being kept clean by the rising of such waters. In such instances the quality of the water is, of course, readily determinable.

Description of the Calyx Drill.—The large calyx drills are driven by horse or steam power. A light yet strong derrick is erected above the well, at the top of which a sheave is placed. From this sheave the drill-rod is suspended by block and tackle,

which is operated by a drum driven by the power turning the drill. (Plate IX.) The feed is thus regulated by the drum, while the turning of the rod is accomplished by a simple arrangement of belting and gears. (Plate X.) The jetting-head is provided with a ball-bearing swivel, thus allowing the rod to turn independent of the water connection and supporting attachment. The surface plant is thus markedly different from that of a diamond drill, which is largely necessitated by the size and weight of the rod. The size of the bore for deep holes ranges from 2⅛ to 10 inches in diameter. As no diamonds are required, there is no reason for taking out small cores.

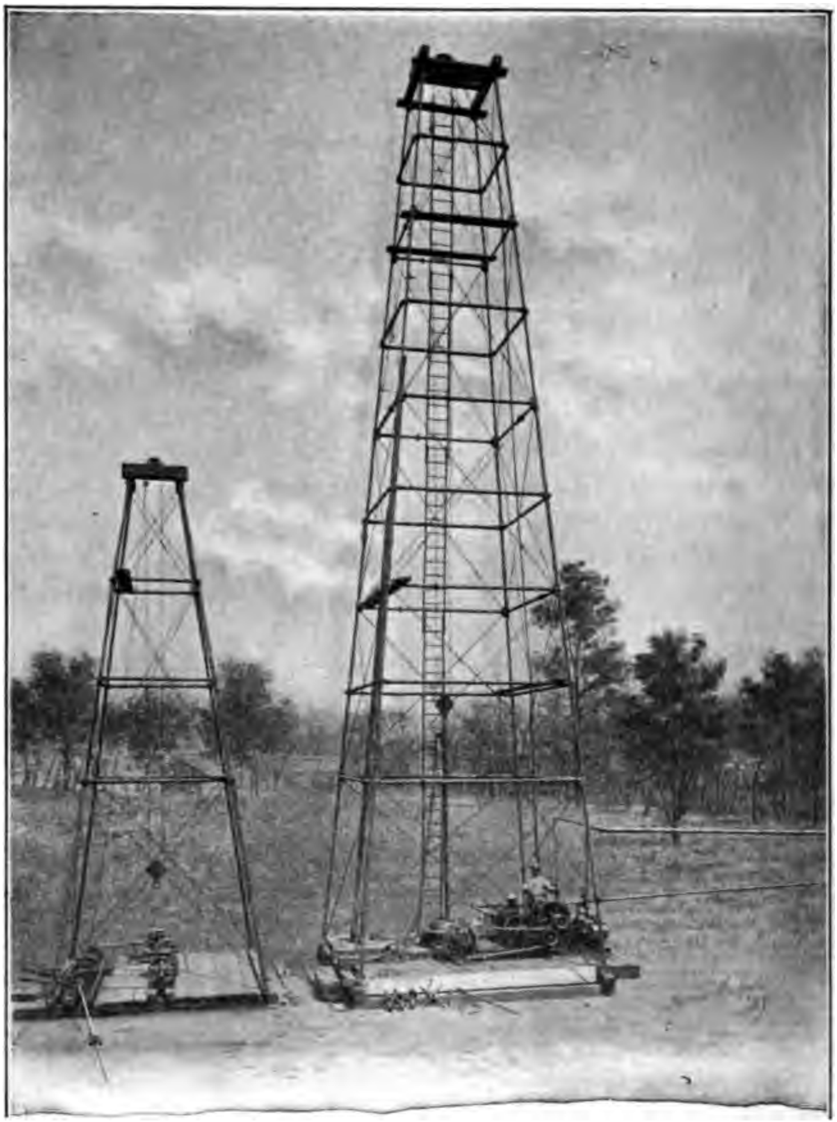
The bit or cutter is a metallic shell, with peculiar teeth in one end, and a thread cut in the other for screwing into the core-barrel.

The core-barrel is a tube, which is always larger in diameter than the drill-rods, but of the same outside diameter as the main body of the cutter.

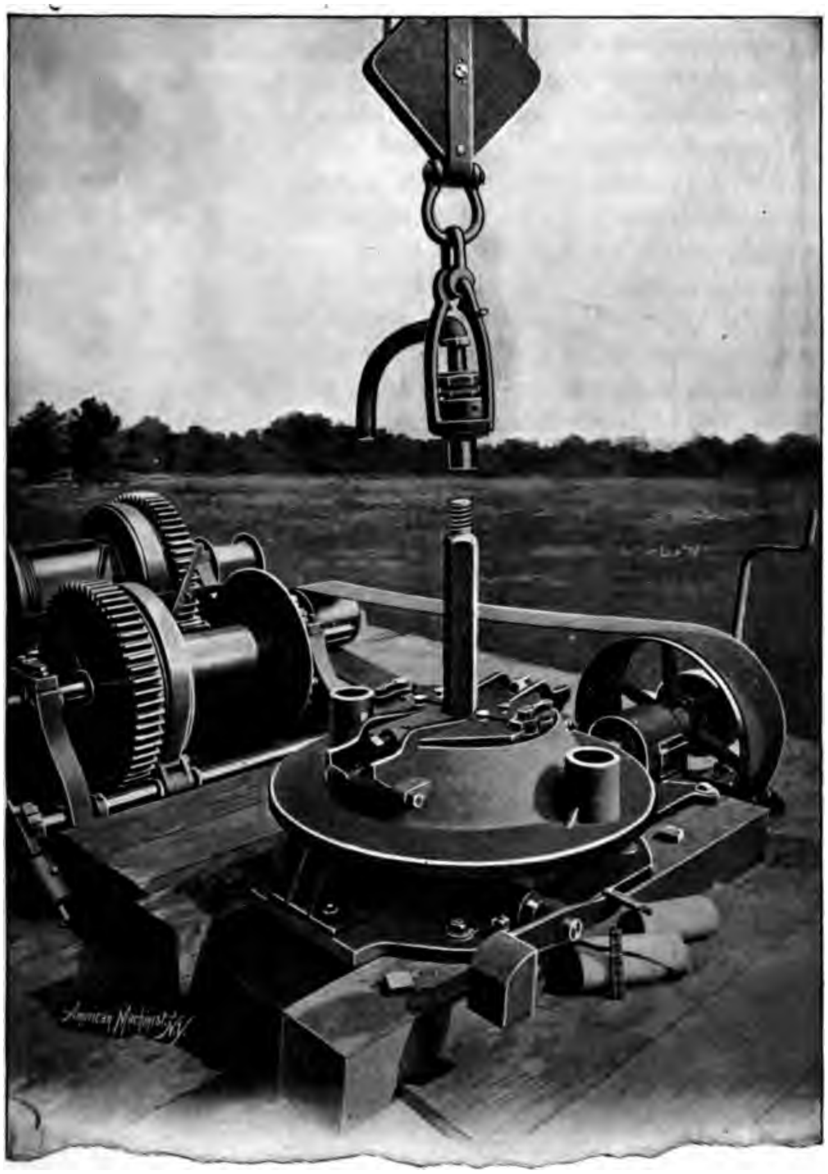
The drill-rods are tubes which screw into the upper end of the core-barrel by means of a reducing plug, and extend downward from the surface.

The calyx is also a tube or series of tubes equal in diameter to the core-barrel. It surrounds the lower drill-rod, rests on the reducing plug, and is open at the upper end, thus leaving a space between the drill-rod and the inside of the calyx. The purpose of this space is explained further on.

Method of Operation of Calyx Drill.—The principle involved in the calyx drill is to all intents and purposes the same as in the diamond drill. In the case of the former, however, drilling is accomplished by means of steel teeth, instead of with diamonds. Here, too, the torsion of the drill-rod is brought into play, the teeth catching on the bottom of the hole, holding until by the torsion or twist of the rod sufficient energy is accumulated to overcome the bite. The instant that the surface strain exceeds the resistance of the turning below, the cutter tears loose, cutting fragments from the groove in which it rests. The strain being relieved, the cutter again comes to rest and is again torn from its bite. The repetition of these movements produces



Davis-Calyx Drill, Surface Plant.



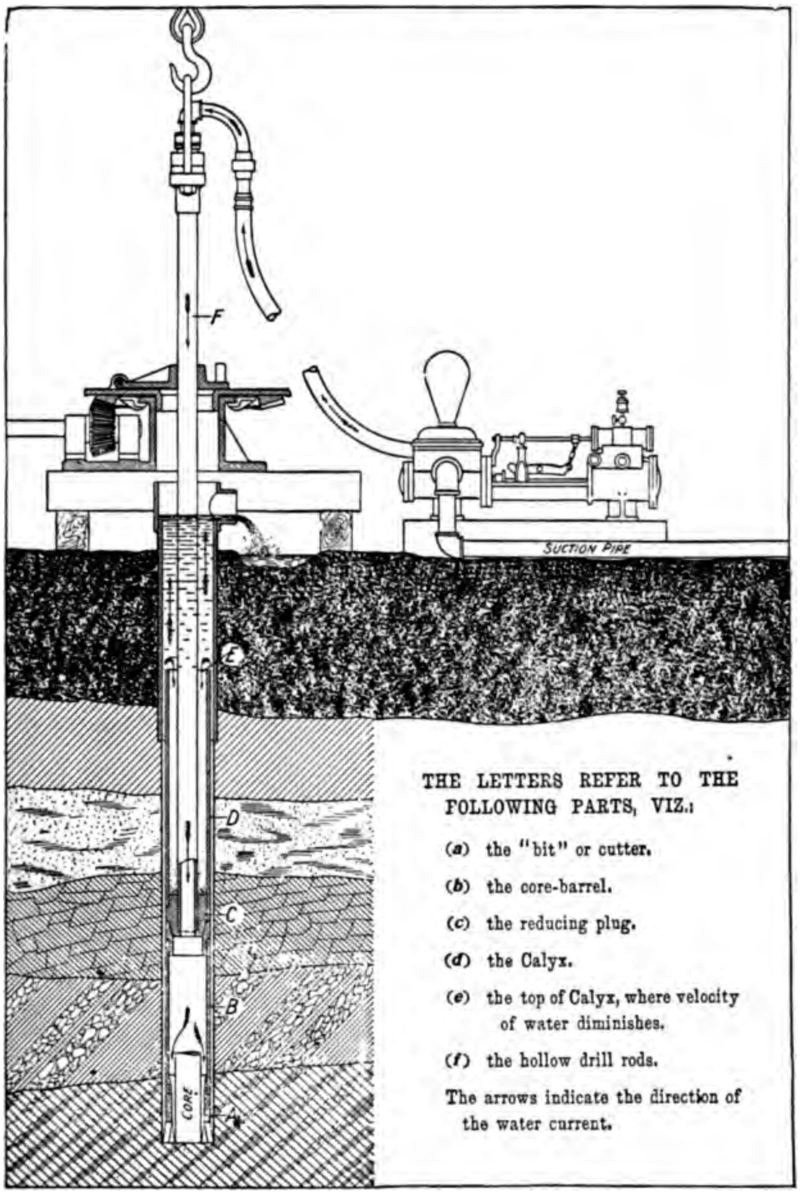
Davis Calyx Drill, Driving Mechanism.

an action which has been likened to that of a mallet and chisel in a stone-cutter's hands.

Water is forced down the rod, as in the diamond drill, through the core-barrel and out between the teeth of the bit or cutter, thence to the surface. The speed of the raising currents will vary with the area of the more or less constricted passage existing between the hole and the drill parts. That part of the distance in which the velocity of the rising currents is greatest is from the bottom of the hole to the top of the calyx tube—the space being small, beyond this upper point the cross-sectional area becomes suddenly enlarged, thus causing a decidedly rapid decrease in the velocity of the currents. The carrying power of the raising currents decreasing with the velocity causes a backward movement or settlement of the materials in suspension, which, being unable to settle against the strong raising currents, are caught in the calyx tube, and that, too, in the order that they occupied in their original position in the strata. Two records are thus obtained—the core and the cuttings or "chip record."

By means of the calyx the hole is kept clear of sludge, the importance of which cannot be too strongly emphasized, not only from the standpoint of free and easy drilling, but also to prevent the "jamming in" of the drill by sludge. The core is removed, sections of rod added and water fed to the rod in a similar manner as is employed in the diamond drill. (Plate XI.)

The speed of the tooth cutter is remarkable in the majority of rocks—many shales and sandstones being cut at the rate of three-fourths inch per revolution. With very hard rock, however, it may be more economical to employ a diamond bit, and, when it is possible, that is, when the size of the hole will allow, such a bit may take the place of the cutter. With the larger sizes this interchange of bits is impossible, or rather impracticable, due to the excessive cost of the diamond bit. It is, therefore, customary to use chilled shot, by the use of which very hard rock can be cut with comparative ease, and that, too, at a low cost. There are, however, some limitations to the chilled-shot process; first, it will not work well in soft, pasty rock;



SECTIONAL VIEW OF DAVIS CALYX DRILL AS IT WOULD APPEAR COULD IT BE SEEN AT WORK UNDERGROUND.

and, second, it will not drill past crevices unless the crevice can be cemented, which in itself is expensive and delays the work. Again, some crevices are too large to cement, while others have streams running through them, thus precluding the idea of cementing.

It is then evident that both the cutter and chilled-shot methods are limited, but one will usually work where the other will not as a rule. To illustrate, say that a very hard stratum of rock is struck while drilling with the cutter, the chilled-shot process can be substituted; again, if a crevice is met, change back to the cutter, which, although it may work slower, may be employed to cut past the objectionable point, cutting a new groove for the shot process again, or cementing may be resorted to.

The chilled-shot process consists in using a blank bit; that is, one without teeth, but having a smooth or annular edge. This blank bit fits into the groove formed by the toothed bit or cutter. On the sides of the bit are grooves reaching to the lower edge. Through these grooves the chilled shot is fed to the bottom of the hole, and as it wears out and is lost, the supply can be maintained. Pressure is given by the weight of the drill-rod above, which, combined with turning, rubs the shot into the rock and thus cut and scour it out, the wash water bearing away the loosened material.

Casing Drill-holes.—Casing consists of placing a wooden or iron lining in the hole in order to maintain its sides. Wood is not used for lining deep-bore holes. Iron or steel are the only suitable materials, and at the same time are fairly inexpensive. Casing is, as a rule, necessary as drilling proceeds, unless the hole is of moderate depth and the formations pierced are solid and will maintain their position until the hole is completed.

In the churn-drill process, there is, in some respects, greater necessity of casing the hole as soon as drilled; that is, keeping the casing a short distance above the bottom, because of the lashing and rubbing of the rope and line of tools against the sides, which causes them to crumble and cave in. The wash

water in the case of the diamond and calyx drills also tends to loosen the soft formation of the walls of the hole, but not to such an extent as does the rubbing of the rope in the churn-drill method.

With the churn drill the hole is made sufficiently large to allow the placing of the casing without extra enlargement. The operation of casing is, in this case, then, quite simple—the casing can be driven from time to time without removing the line of tools. This is accomplished by raising the tools until the middle of the sinker-bar comes to the top of the casing; a driving block is then clamped to the bar, which, being raised and dropped will drive the casing down. Sections are added as needed until the full depth has been lined. When drilling is done by diamond or calyx drills, the hole must be reamed out to make room for the casing, provided casing is necessary during drilling operations. Reaming will then alternate with drilling.

It is often necessary to shut off certain strata to pervent the contamination of the desired product, as when oil, gas and briny-water strata overlie the sheet of water which it is desired to open up. Such strata may be closed after the hole is completed, but it is usually preferable to close the same as soon as possible after penetration. Quicksand strata must be closed at once, or further work of drilling will be interfered with, and there will also be the risk of a cave-in.

It was formerly necessary to remove the bit and core-barrel and substitute for them a reamer, but within the last few years a reamer has been devised by means of which drilling and reaming may be carried on simultaneously, thus allowing the casing to be placed and driven from time to time independent of drilling operations. The driving of the casing is accomplished in this case by an improvised pile driver, the rod being removed during the operation.

When it is especially desirable to close the strata as soon as passed through it may be done by a new device lately brought into practical use, which is intended, however, for shallow work only, as working gravel beds and superficial coverings.

The casing is driven continuously and at the same rate that drilling is carried on, thus maintaining the same distance between the bit and the bottom of the casing. This is accomplished by a driving block, which is attached to the cable or a rod connecting with the line of tools. The weight of the tools drives the casing.

As the wells discussed in this report are under 1500 feet in depth many of the difficulties encountered in drilling holes up into the thousands of feet are not experienced; then, too, the formations met with are with a few possible exceptions easily worked with all forms of drilling devices.

In several localities, especially in the southeastern portion of the state, a very hard limestone, commonly called "bastard rock," is found, but by far the most difficult formation to drill is the cherty formation of Galena, which is not only very hard but is in most parts fissured. Diamond drills cannot conveniently be employed in such rock, and churn drills are frequently troubled by the catching of the tools. The calyx drill, using both the cutter and chilled shot, together with cementing, can readily cope with such conditions.

The self-contained forms of churn drills are largely used for the drilling of wells and for prospecting purposes, especially in prospecting for oil, gas, and coal.

Opening Up and Clearing Out Wells.—When a well has been sunk to the stratum in which water is known or believed to occur and nothing is found, or it is obtained in such small quantities as to be of no special value, it is usual to try opening up the bottom of the hole. This is accomplished by firing off a charge of explosive, usually nitroglycerin, which has been lowered to the desired point. A cavity is then formed or the formation is greatly disturbed and fissured, thus producing a large area of fissured and broken rock through which the water can readily pass to the hole. The same method of procedure is often followed with a well which has been yielding a sufficient supply but begins to fall off or ceases altogether.

It is not uncommon, however, to bring about results exactly the reverse of what is expected, namely, the entire cutting off of the supply. Several cases are on record where very good wells have been rendered worthless by such a process of opening up or clearing out.

CHAPTER IX.

ARTIFICIAL MINERAL WATERS AND CARBONATED BEVERAGES.

Although attempts were made very early to imitate natural mineral waters, but little progress was made until after the discovery of carbon dioxid by Doctor Black in 1757 and its analysis by the French chemist, Lavoisier. It was, however, to Priestley, the English chemist, that we must give the credit of first proposing, in 1772, to impregnate ordinary water with carbon-dioxid gas, and in accordance with this suggestion prescriptions were published in 1774 for the artificial production of Seltzers and other carbonated waters. From Liebig's analysis of the Friedricksaller an artificial water was easily prepared.

Prof. Torbern Olof Bergman, a Swedish chemist, did much to introduce the use of artificial mineral water. As he had been greatly benefited by the use of mineral waters obtained from Germany, and as at some times of the year it was difficult to obtain them, he analyzed the waters and compounded artificial imitations with great success. He saturated water with carbonic "aerial" acid gas, and added to this the required quantity of mineral salts. He probably used the "agitator" devised by the French Duke de Chaulnes in the process of carbonating.

The Seltzer waters were made in 1787 on a large scale by Meyer, at Stettin, Germany. Paul erected a factory for the same purpose in Paris in 1799. In Great Britain a patent for impregnating water with carbon-dioxid gas was taken out in 1807, and a similar patent was taken out in Charleston, S. C., in 1810. Doctor Struve, in 1815, in the city of Dresden, began the manufacture of artificial mineral waters, ex-

actly imitating those found in nature, and the same physician introduced these waters into medical use. More recently this business has been greatly extended all over the world, and at present imitations of all the famous natural mineral waters are prepared in the laboratory. Indeed, after a study of the composition of a particular water, the bottler prepares a similar beverage, which is not identical, however, because certain substances, considered of no use, are left out in compounding.

By the use of carbon dioxid it is possible to hold in solution mineral substances which would otherwise be precipitated as soon as the water is exposed to the air. This is especially true of the compounds of manganese, iron, calcium, and magnesium. It is probable that the carbonic-acid gas is of service also in displacing the air, and so preventing oxidation and sometimes deterioration of the waters.

The manufacturer of the artificial mineral water uses, as far as possible, ingredients which will, when added to water and carbonated, give constituents similar to those in the natural water. These chemical salts must be of such a character that they will not be incompatible or precipitate each other. The recently precipitated hydroxids or carbonates are much more soluble than the ordinary dry salts, and, in the process of compounding, groups of substances *in solution* are added in a definite order. Some substances, such as citric acid or sodium pyrophosphate, are often added as "preservatives" of these artificial waters, the object being especially to keep iron in solution.

THE MANUFACTURE OF CARBON-DIOXID GAS.

Since the time of Priestley, who, in 1772, made an apparatus for the production of "fixed air," as he called it, from a mixture of chalk and "oil of vitriol," to the present time, a great deal of ingenuity has been expended on apparatus for this purpose.[43] Historically considered, the following types of apparatus have been introduced:

The Geneva or Semi-continuous System.—This is the old form of generator used in Europe. The gas was generated in a

43. A Treatise on Beverages, or the Complete Practical Bottler, Chas. H. Sulz.

wooden cylinder, passed into a gasometer or storage tank, then by means of a force-pump into a strong cylinder containing water and provided with an agitator. By this plan, after one "batch" of gas was used the apparatus had to be cleaned out.

The Continuous System.—In this "direct-action" process, as it is called, the gas is generated in a leaden vessel, just enough acid being brought in contact with the carbonate, usually mixed with water, to generate the gas. Then the gas is washed through water and allowed to expand in a "gasometer." The "soda-water machine" proper consists of a force-pump, which pumps, at the same time, water and gas into a strong cylinder, provided with an agitator to assist in the solution of the gas in the water.

The Intermittent System.—By this plan the gas is dissolved in water by the pressure produced in the generator from the chemical action of the acid on the carbonate, without the aid of a pump or gasometer. Of course, the greater the pressure the more gas the water will dissolve. In order to make the apparatus continuous, it is only necessary to have several generators, two at least, so that the material in one apparatus may be renewed while the other is in use. There are often pumps attached to the apparatus as used in the United States, for filling the cylinders with water. The generators may be so arranged as to be horizontal and acid-feeding, or vertical and carbonate-feeding.

The Liquid Carbonic-acid System.—This is the most recent, and bids fair to supplant all the other systems in localities easily reached by transportion. The liquefied gas, made by one of the processes mentioned below, is pumped into strong wrought-iron cylinders about four feet long by five inches in diameter. These cylinders are tested to stand four times the pressure that they ordinarily bear, and hold about twenty pounds of the liquified gas. This represents about 1100 gallons of gas at ordinary atmospheric pressure, and will charge from 200 to 300 gallons of water, according to the pressure desired. As this gas can be purchased at twelve cents or less per pound, it it is evident that,

considering the convenience to the manufacturer and dealer, and because it makes it unnecessary to run a somewhat cumbersome machine, the liquefied gas will be extensively used. Even large wholesale bottlers buy the gas in preference to making it.

MATERIALS USED IN THE MANUFACTURE OF CARBON-DIOXID GAS.

In order to make this gas, a carbonate—as sodium carbonate (Na_2CO_3), sodium bicarbonate ($NaHCO_3$), or marble dust ($CaCO_3$)—is used, together with an acid, as sulfuric (H_2SO_4), or hydrochloric (HCl). The cheapest carbonate and the cheapest acid would be selected, other things being equal. The chemist represents the reaction by $CaCO_3+H_2SO_4=CaSO_4+H_2O+CO_2$. Water and calcium sulfate are left in the generator after the chemical action is over. The carbon-dioxid gas might also be made by the simple combustion of charcoal or coke, but this gas is not very readily purified. Another method of making is by simply heating limestone; thus, $CaCO_3+\text{heat}=CaO+CO_2$. The calcium oxid left can be utilized as quicklime.

Another and recent source of the gas is from the vats in which beer is fermenting. By the process of malting some of the starch of the grain is changed into a kind of sugar and this ferments readily with yeast, the products being alcohol and carbon-dioxid gas. The carbon-dioxid gas is pumped off and condensed to a liquid by pressure. The gas obtained in this way must be thoroughly washed and purified before being used. In fact, a process of washing is necessary to purify the gas in whatever way it is made. Sometimes washing with simple water is sufficient, and in other cases more thorough washing through chemical solutions is necessary. This gas finds many uses in the arts. In England it is used instead of yeast in the manufacture of "aerated bread."

PROPERTIES OF CARBON DIOXID.

This gas is much heavier than air, will extinguish a fire, and is not poisonous. As stated above, it may be condensed to a liquid, and when some of this liquid is allowed to escape into the air it vaporizes so rapidly that it takes heat from the surrounding gas and converts it into a snow-white solid. This

solid is so cold that it will freeze mercury readily, if brought into contact with it. As noticed above, the carbon-dioxid gas is very soluble in water, and, as the pressure is increased, the colder the water the more is dissolved.

METHODS OF USING THE LIQUEFIED CARBON-DIOXID GAS.

There are numerous "carbonators" on the market for use with the liquified gas. The principle on which they work is as follows: The cylinder containing the liquified gas is attached to a pressure gauge and to the carbonator by means of heavy block-tin pipes. The gas is led into an agitator, where it passes through the water, and then into a cylinder, where it is sprayed with the incoming water. It is important that all air in the apparatus be allowed to escape. A pump is used to run the agitator and at the same time to pump water into the mixing cylinder. By means of an automatic arrangement the pump is stopped whenever the water rises to a fixed height in the mixer, and starts again when the liquid has been drawn off below a certain level. The pressure of the charged water can be regulated at will, so that the machine thus furnishes a continuous supply of carbonated water.

As the liquefied gas cools the cylinders rapidly when it escapes, so, in order to prevent a stoppage of the valves by freezing, some manufacturers pass the gas through a steam-jacketed tube to warm it, while others attach several "drums" to one carbonator at the same time, so that the gas shall not expand so rapidly in any one of them as to cause inconvenience.

The liquefied gas is also used in small steel capsules, known as "sparklets," for carbonating mineral water and other beverages. The capsules are closed with a thin steel cap which, when placed in position in a syphon apparatus, may be punctured by a steel needle, allowing the gas to come in contact with the water.

This gas is of great use in the carbonating of natural mineral waters, so as to keep in solution mineral substances that would otherwise separate out when standing, and also to improve the taste of a water by the additional flavor and effervescence of the gas.

CARBONATED AND SACCHARINE BEVERAGES.

The manufacture of soda-water, pop, ginger ale, sarsaparilla and such beverages is so closely related to that of artificial mineral water that it should be discussed in this connection.

It is important that the water used be of good quality, but there is reason to believe that some manufacturers are careless in this respect. The effect of great pressure, lack of oxygen and the presence of carbon dioxid in the water, on the microbes that might exist there, has received considerable study. Doctor Leone, who examined the water-supply of Munich, showed by a series of experiments that, in a sample of carbonated water, the number of microbes diminished in fifteen days from 186 to 20. He further showed that this decrease in numbers was not due to deficiency of oxygen, nor to great pressure, but to the presence of carbon dioxid in the water. This would seem to indicate, then, that in the use of ordinary carbonated beverages the consumer is, to some extent, protected from the micro-organisms which are present in impure water.

In addition to the water and the carbon dioxid-gas, the bottler uses some or all of the following substances, each of which should be of good quality and standard strength:

1. Sweetening material: Cane sugar, if used for this purpose, should be pure, and free from "bluing" or glucose. Glucose or grape sugar is often used. This has only about three-fourths the sweetening power of cane sugar. It is made by the action of sulfuric acid on starch and the subsequent neutralizing of the solution with marble dust. Competent chemists and physicians have pronounced it, if carefully made, a wholesome sweetening material, but it renders the beverages very liable to fermentation. Honey may be used for sweetening, but, on account of its market value, it is very liable to adulteration. Saccharin ($C_6H_4CO\ SO_2\ NH$), which is not a sugar at all but a sweet substance made in the laboratory from coal-tar, is a remarkable product which is coming into very extensive use. Cane sugar can scarcely be detected by the sense of taste in a solution that contains 1 part in 250 parts of water, but saccharin can be detected in a solution containing but 1 part in

70,000 parts of water. It is not usually considered injurious to the human system, though there are some who hold an opposite opinion. It is something of an antiseptic, and does not ferment like sugars.

2. Fruit syrups made from genuine fruits are used. These may be made from fermented or unfermented juices, and are sometimes "animated" by the addition of a little artificial fruit essence.

3. Compound syrups have the most extended use and are made from a great variety of organic ethers and other substances.

4. In many of these preparations coloring matters, made from organic dyestuffs or aniline colors, are employed.

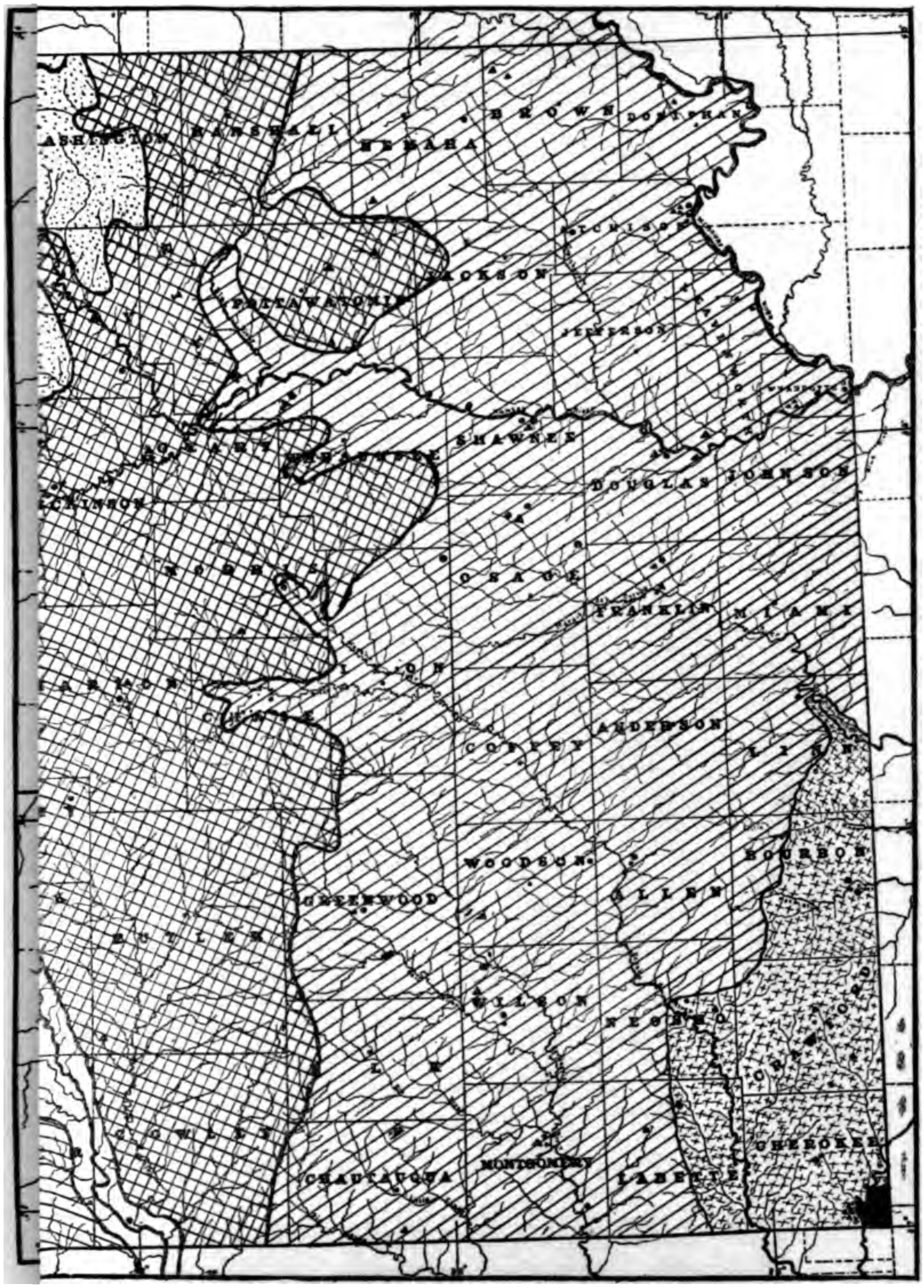
5. Essential oils and extracts of vegetable origin in great variety are used for flavoring.

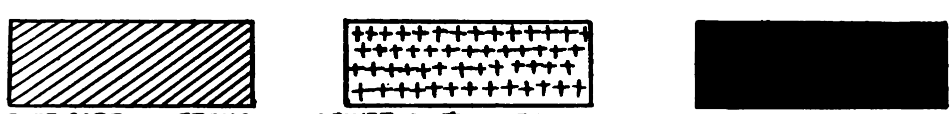
The manufacturer of these beverages, in bottling, simply allows a measured quantity of the flavored and prepared syrup to flow, by means of a block tin pipe, into the bottle placed in the bottling-machine, and it is then immediately filled with the carbonated water, under pressure of perhaps eighty pounds to the square inch, and is closely corked.

GEOLOGICAL MAP OF KANSAS,

Showing the position of Springs and Wells.

By W. R. CRANE.





UPPER-CARBONIFEROUS LOWER-CARBONIFEROUS SUB-CARBONIFEROUS

ɪINGS AND WELLS.

PART II.

THE MINERAL WATERS OF KANSAS,

ARRANGED AND CLASSIFIED, WITH ANALYSES.

Waters from the springs and wells referred to in Part II of this report are classified as follows:

I.—The Chlorid Group.
II.—The Sulfate Group.
III.—The Chlor-sulfate Group.
IV.—The Carbonate Group.
V.—The Chlor-carbonate Group.
VI.—The Sulfid Group.
VII.—The Chalybeate Group.
VIII.—The Special Group.
IX.—The Soft-water Group.

See methods of classification, p. 98.

As has been previously stated, it is not possible to make a sharp and perfect classification of the waters, as the ingredients vary in quality and quantity, so that, while in most cases there is no doubt where a water should be classified, there are some waters that belong with equal propriety to two or possibly three groups. In some cases, therefore, a water is mentioned in several groups, but the description of locality, analysis, etc., is given only once, in what appears to be its most proper location. When it occurs in other lists it is bracketed, thus (............).

CHAPTER X.

THE CHLORID GROUP.

Waters of this class are generally called "brines," although many of them do not contain a sufficient quantity of sodium chlorid to be workable for salt, or they contain too many foreign ingredients to be of use.

The chlorid waters are obtained from the solution of the salts that have been left after the drying up of some ancient ocean. It is said that they show their relation to the ancient seas rather than the modern, because they contain calcium chlorid or sulfate, as well as chlorids of the alkalies and magnesium chlorid, salts which are present in modern sea water. Waters of this class are frequently called "saline," from the abundance of common salt which they contain, although some have objected to this term as a misnomer, since all mineral waters contain "salts" in the ordinary chemical acceptation of the term.

Since the ocean is the great storehouse of bromids and iodids, we find that these waters often contain both these ingredients. We look here also for waters rich in magnesium. Waters of the chlorid group have found their most important use for bathing purposes, although, diluted with soft water, they may be used internally. Some waters that are classified here as brines are already diluted in nature, and as such may be used internally.

This group is represented by the following waters:

Abilene, Dickinson county, artesian well.

Arkansas City, Cowley county.

Atchison, A. B. C. laundry well.

Atchison, Becker's well.

Atchison, diamond drill prospect well.

Eureka, Greenwood county.

Fay, Russell county.
Fredonia, Wilson county.
Geuda Springs, Cowley county.
Independence, Montgomery county, Brom-magnesian well.
Lawrence, Douglas county, artesian well.
Leavenworth, "Ocean Spray."
Marion, Marion county, lower vein.
Mound City, Linn county.
Mound Valley, Labette county.
Overbrook, Osage county, No. 2 well.
Rosedale, Johnson county, Geyser well.
Saint Paul, Neosho county.

Abilene Artesian Well, Dickinson County.

In the fall of 1901 the Abilene Oil and Gas Company drilled a five-inch well, or prospect hole, 1260 feet in depth. A pipe twenty feet long extended above the surface of the ground, and the water rises in the well and overflows this pipe. It was proposed to drive the boring still deeper, but on account of the discovery of such an abundant salt-water supply, the work has been stopped for the present. The water is nearly clear, and has a salt and astringent taste. The reaction is strongly acid, and upon being heated the water becomes yellow from the presence of iron chlorid, and gives off free hydrochloric-acid gas. The analysis is as follows:

ABILENE ARTESIAN WELL.
Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	56.4721	Sodium oxid (Na_2O)	76.1080
Potassium (K)	trace	Potassium oxid (K_2O)	trace
Calcium (Ca)	8.6709	Calcium oxid (CaO)	12.1340
Magnesium (Mg)	2.7264	Magnesium oxid (MgO)	4.5840
Iron (Fe)	.0801	Iron oxid (FeO)	.1030
Manganese (Mn)	trace	Manganese oxid (MnO)	trace
Chlorin (Cl)	110.2785	Chlorin (Cl)	110.2785
Bromin (Br)	.5152	Bromin (Br)	.5152
Iodin (I)	.0063	Iodin (I)	.0063
Sulfuric acid ion (SO_4)	.1249	Sulfuric anhydrid (SO_3)	.1040
Silicic acid ion (SiO_3)	.0114	Silicic anhydrid (SiO_2)	.0090
Hydrogen ion	trace	Oxygen equivalent	24.9853
		Total	178.8567

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	142.9970	8352.454
Sodium bromid (NaBr)	.6633	38.743
Sodium iodid (NaI)	.0074	.432
Potassium sulfate (K_2SO_4)	trace	trace
Calcium chlorid ($CaCl_2$)	23.9070	1396.408
Calcium sulfate ($CaSO_4$)	.1768	10.326
Magnesium chlorid ($MgCl_2$)	10.8870	635.910
Iron chlorid ($FeCl_3$)	.2092	12.219
Manganese chlorid ($MnCl_2$)	trace	trace
Silica (SiO_2)	.0090	.526
Totals	178.8567	10447.018

Specific gravity, 1.112.
Analysis by E. H. S. Bailey and F. B. Porter.

Arkansas City Well.

This well is located on the farm of Rheinhold Hess, southeast of the city. It is bored to a depth of 250 feet, the last part through a loose gravel and rock. The water is used for bathing and drinking purposes. Arkansas City is on the line of the Frisco, Santa Fe and the Missouri Pacific railroads.

IMPROVEMENTS.

The proprietor has built here a small bath-house, in which hot, cold, shower and vapor baths are given. Water escapes continually from the well. In order to get large quantities it is necessary to use a pump. Considerable gas is given off from the water when it is first drawn.

The composition of the water is as follows:

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	13.1735	Sodium oxid (Na_2O)	17.7349
Calcium (Ca)	.3060	Calcium oxid (CaO)	.4284
Magnesium (Mg)	.2581	Magnesium oxid (MgO)	.4302
Aluminum (Al)	.0141	Aluminum oxid (Al_2O_3)	.0266
Sulfuric acid ion (SO_4)	3.6226	Chlorin (Cl)	18.7740
Silicic acid ion (SiO_3)	.2671	Sulfuric anhydrid (SO_3)	3.1230
		Silicic anhydrid (SiO_2)	.2118
		Less oxygen equivalent	4.2427
		Total	36.4862

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Calcium sulfate ($CaSO_4$)	1.0414	60.8282
Magnesium sulfate ($MgSO_4$)	1.2916	75.4423
Sodium sulfate (Na_2SO_4)	2.9298	171.1290
Sodium chlorid (NaCl)	30.9850	1809.8339
Alumina (Al_2O_3)	.0266	1.5534
Silica (SiO_2)	.2118	12.3712
Totals	36.4862	2131.1589

Analysis by E. H. S. Bailey.

Atchison County Mineral Waters.

In a paper read before the Kansas Academy of Science,[41] Prof. E. B. Knerr says: "The drift in Atchison county is quite uniform in structure, being a heavy compact clay for the most part, with but little sand and gravel intermixed. Water will pass through it very slowly; hence the wells dug into it are deep, as a rule, usually from forty to sixty feet in depth, and the water generally stands quite low, though about three feet of water may generally be counted upon in the dryest months. Such wells at these seasons may easily be pumped dry, but in the course of several hours the water will collect to the depth of a foot or two again. Analysis of this drift water presents nothing of unusual interest.

"There are numerous springs in Atchison county. Where these issue from the limestone they are of interest only as furnishing good, cool drinking water. Several such springs occur within the city limits of Atchison and have always supplied the neighborhoods in the vicinity with water."

The A. B. C. Laundry Well, Atchison.

This is an example of a comparatively shallow well yielding salt water, for the depth is only sixty-three feet. Wells 200 feet in depth in this locality generally yield salt water. As an example of water from the deepest well, attention is called to the diamond-drill prospect boring.

41. Trans. Kans. Acad. Sci., vol. IV, p. 88.

This water has the following composition:

A. B. C. LAUNDRY WELL.

Grams per Liter.

IONS.		RADICALS.	
Sodium (Na	.4827	Sodium oxid (Na_2O)	.6506
Potassium (K)	trace	Potassium sulfate (K_2SO_4)	trace
Calcium (Ca)	.0340	Calcium oxid (CaO)	.0475
Magnesium (Mg)	.0067	Magnesium oxid (MgO)	.0110
Iron (Fe)	.0231	Iron oxid (FeO)	.0296
Chlorin (Cl)	.7450	Chlorin (Cl)	.7450
Sulfuric acid ion (SO_4)	.0219	Sulfuric anhydrid (SO_3)	.0182
Silicic acid ion (SiO_3)	.0558	Silicic anhydrid (SiO_2)	.0447
		Water of combination (H_2O)	.0235
		Carbonic anhydrid (CO_2)	.1152
		Oxygen equivalent	.1676
		Total	1.5177

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	1.2278	71.7158
Potassium sulfate (K_2SO_4)	trace	trace
Calcium sulfate ($CaSO_4$)	.0310	1.8107
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.1005	5.8702
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.0404	2.3598
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0733	4.2814
Silica (SiO_2)	.0447	2.6109
Totals	1.5177	88.6488

Analysis by E. B. Knerr.

Atchison Diamond Drill Prospect Boring.

In the summer of 1900 a well 1353 feet in depth, penetrating into the Mississippian limestone for the last thirty-eight feet, was bored at Atchison, for the purpose of investigating the coal seams beneath the city. The total cost of this well was about $4700, which amount was mostly raised by public subscription. The drill, which brought up a 2-inch core, penetrated in all fourteen feet and five inches of coal, a 36-inch seam being found at a depth of 1123 feet, and a 28-inch seam being found at a depth of 1188 feet. Samples of water were taken at different depths, and all proved to be brines. The analysis of the water taken at the greatest depth, which, of course, would be more or less a mixture of all the different streams which found their

way into the well, is given herewith. A complete report made by A. E. Langworthy[45] of the boring and log of the well has been preserved, and the core is deposited with the Geological Department of the University.

The analysis is as follows:

ATCHISON DIAMOND DRILL PROSPECT BORING.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	9.8016	Sodium oxid (Na_2O)	13.1937
Potassium (K)	trace	Potassium oxid (K_2O)	trace
Calcium (Ca)	.5699	Calcium oxid (CaO)	.7846
Magnesium (Mg)	.1231	Magnesium oxid (MgO)	.2058
Iron (Fe)	.0618	Iron oxid (FeO)	.0795
Chlorin (Cl)	15.0660	Chlorin (Cl)	15.0660
Iodin (I)	trace	Iodin (I)	trace
Sulfuric acid ion (SO_4)	.0188	Sulfuric anhydrid (SO_3)	.0157
Silicic acid ion (SiO_3)	.3560	Silicic anhydrid (SiO_2)	.2812
Nitric acid ion (NO_3)	trace	Nitric anhydrid (N_2O_5)	trace
		Carbonic anhydrid (CO_2)	1.7658
		Water of combination (H_2O)	.3623
		Oxygen equivalent	3.4052
		Total	28.3494

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	24.8550	1451.780
Sodium iodid (NaI)	trace	trace
Potassium nitrate (KNO_3	trace	trace
Calcium sulfate ($CaSO_4$)	.0266	1.554
Calcium bicarbonate ($CaH_2(CO_3)_2$)	2.2388	130.768
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.7518	43.912
Iron bicarbonate ($FeH_2(CO_3)_2$)	.1960	11.448
Silica (SiO_2)	.2812	16.424
Totals	28.3494	1655.886

Analysis by E. H. S. Bailey and F. B. Porter.

Becker's Mineral Well, Atchison.

In the western part of the city, in the valley of the White Clay, on West Main street, a well 125 feet deep has been drilled on the property of Peter Becker. When first drawn the water is surcharged with carbon-dioxid gas and is perfectly clear, but

45. Trans. Kans. Acad. Sci., vol. XVII, pp. 45-52.

after standing a while the gas escapes and the water becomes turbid on account of the deposition of iron hydrate.

IMPROVEMENTS.

The improvements on this property are convenient bathrooms, supplied with the usual facilities for taking hot and cold saline baths.

BECKER'S WELL.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	10.1000	Sodium oxid (Na_2O)	13.6148
Potassium (K)	.0360	Potassium oxid (K_2O)	.0435
Ammonium (NH_4)	.0200	Ammonium hydroxid (NH_4OH)	.0288
Calcium (Ca)	.4200	Calcium oxid (CaO)	.5880
Magnesium (Mg)	.3100	Magnesium oxid (MgO)	.5164
Iron (Fe)	.0420	Iron oxid (FeO)	.0540
Chlorin (Cl)	15.5500	Chlorin (Cl)	15.5500
Sulfuric acid ion (SO_4)	1.1088	Sulfuric anhydrid (SO_3)	.9240
Phosphate ion (PO_4)	.0241	Phosphoric anhydrid (P_2O_5)	.0180
Silicic acid ion (SiO_3)	.0228	Silica (SiO_2)	.0180
		Carbonic anhydrid (CO_2)	1.2254
		Water of combination (H_2O)	.2528
		Oxygen equivalent	3.5035
		Total	29.3300

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Potassium sulfate (K_2SO_4)	.0804	4.6835
Sodium sulfate (Na_2SO_4)	.0425	2.4813
Sodium phosphate (Na_2HPO_4)	.0060	2.1000
Sodium chlorid (NaCl)	25.6264	1495.0000
Ammonium sulfate ($(NH_4)_2SO_4$)	.0730	4.2580
Calcium sulfate ($CaSO_4$)	1.3920	81.1950
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.0431	2.5142
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	1.8851	109.9600
Iron bicarbonate ($FeH_2(CO_3)_2$)	.1335	7.7870
Silica (SiO_2)	.0180	1.0498
Totals	29.3300	1711.0288

Specific gravity, 1.02007; temperature, 14° C. (57° F.)

Analysis by E. B. Knerr.[46]

46. Trans. Kans. Acad. Sci., vol. XV, p. 89.

Fourth Avenue Hotel, Eureka.

Bath-house Hotel, Geuda Springs.

Eureka Mineral Well.

In 1887 a well 140 feet deep was bored in Eureka, Greenwood county. At a depth of thirty-six feet rock was struck, and the boring was continued through this for 100 feet, till an abundance of water was found. The water was for several years quite extensively used for bathing and drinking.

IMPROVEMENTS.

The well is situated on the grounds of the Fourth Aveuue hotel, opposite and directly north of the court-house. Bathrooms are provided, with modern improvements. The property was originally developed by A. P. Cogswell, was later owned by Dr. S. J. Carpenter, and has now passed into other hands. The hotel has accommodations for perhaps twenty guests, but the mineral water is not used extensively at the present time.

Eureka is the county-seat of Greenwood county, and is on the A. T. & S. F. and the Mo. Pac. railroads.

EUREKA MINERAL WELL [47]

Grams per liter.

IONS.		RADICALS.	
Potassium (K)	.0691	Potassium (K_2O)	.0833
Sodium (Na)	2.6983	Sodium oxid (Na_2O)	3.6369
Calcium (Ca)	.2591	Calcium oxid (CaO)	.3626
Magnesium (Mg)	.1101	Magnesium oxid (MgO)	.1835
Iron (Fe)	.0008	Iron oxid (FeO)	.0011
Aluminum (Al)	.0009	Aluminum oxid (Al_2O_3)	.0017
Chlorin (Cl)	4.3919	Chlorin (Cl)	4.3919
Bromin (Br)	.0004	Bromin (Br)	.0004
Iodine (I)	.0001	Iodine (I)	.0001
Sulfuric acid ion (SO_4)	4.5801	Sulfuric anhydrid (SO_3)	.4834
Phosphoric acid ion (PO_4)	.0006	Phosphoric anhydrid (P_2O_5)	.0003
Boric acid ion (BO_4)	trace	Boric anhydrid (B_2O_3)	trace
Nitric acid ion (NO_3)	trace	Nitric anhydrid (N_2O_5)	trace
Silicic acid ion (SiO_3)	.0162	Silica (SiO_2)	.0137
Organic matter	trace	Carbonic anhydrid (CO_2)	.2158
		Water of combination (H_2O)	.0409
		Oxygen equivalent	.9913
		Total	8.4243

47. Trans. Kans. Acad. Sci., vol. XII, pp. 28, 29.

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Potassium sulfate (K_2SO_4)	.1272	7.4297
Sodium chlorid (NaCl)	6.8631	400.8736
Sodium bicarbonate ($NaH_2(CO_3)_2$)	trace	trace
Sodium nitrate ($NaNO_3$)	trace	trace
Sodium bromid (NaBr)	.0005	.0292
Sodium iodid (NaI)	.0001	.0058
Sodium phosphate ($NaHPO_4$)	.0006	.0351
Calcium sulfate ($CaSO_4$)	.7225	42.2012
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.1883	10.9986
Magnesium chlorid ($MgCl_2$)	.3107	18.1480
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.1924	11.2382
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0035	.2044
Alumina (Al_2O_3)	.0017	.0993
Silica (SiO_2)	.0137	.8002
Totals	8.4243	492.0633

Analysis by E. H. S. Bailey.

Fay, Russell County.

An artesian well on farm of C. H. Kellogg, called "Artesian Ranch," at Fay, was drilled in 1894 to a depth of 121 feet. It is located on southeast quarter of section 14, township 12, range 15 west, Paradise township. The flow is said to be 1000 barrels in twenty-four hours, and the water has a pressure of fifteen pounds per square inch. The water has not been advertised, but has a local reputation as a valuable medicinal agent.

The following is the composition:

FAY ARTESIAN WELL.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	4.921	Sodium oxid (Na_2O)	6.627
Potassium (K)	.039	Potassium oxid (K_2O)	.048
Calcium (Ca)	.171	Calcium oxid (CaO)	.240
Magnesium (Mg)	.282	Magnesium oxid (MgO)	.470
Chlorin (Cl)	6.742	Chlorin (Cl)	6.742
Sulfuric acid ion(SO_4)	2.068	Sulfuric anhydrid (SO_3)	1.722
		Carbonic anhydrid (CO_2)	.297
		Total	16.146

Temperature, 13.3° C. (56° F.); specific gravity, 1.0109.
Analysis by G. H. Failyer.

Hudson Well, Fredonia.[48]

This gas-well is four miles south and one mile west of Fredonia. The depth is 1175 feet, and the salt water comes in at a depth of 400 feet. The flow is estimated at five barrels per hour. Gas was first struck at a depth of 325 feet, and a second and stronger stratum at a depth of 1150 feet. Oil was also struck at a depth of 1100 feet, in sufficient quantity to pump.

HUDSON WELL, FREDONIA.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	2.7907	Sodium oxid (Na_2O)	37.4788
Calcium (Ca)	1.4246	Calcium oxid (CaO)	2.0147
Magnesium (Mg)	2.8443	Magnesium oxid (MgO)	4.7398
Iron (Fe)	.0561	Iron oxid (FeO)	.0722
Chlorin (Cl)	49.2850	Chlorin (Cl)	53.6533
Bromin (Br)	.0790	Bromin (Br)	.0790
Iodin (I)	.0084	Iodin (I)	.0084
Sulfuric acid ion (SO_4)	.0397	Sulfuric anhydrid (SO_3)	.0314
Silicic acid ion (SiO_3)	.0550	Silicic anhydrid (SiO_2)	.0434
		Carbonic andhyrid (CO_2)	.1097
		Water (H_2O)	.0224
		Oxygen equivalent	12.1307
		Total	86.1224

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	70.5133	4118.6819
Sodium bromid (NaBr)	.1016	5.9344
Sodium iodid (NaI)	.0106	.6191
Sodium bicarbonate ($NaHCO_3$)	.0414	2.4181
Calcium chlorid ($CaCl_2$)	3.9461	230.4918
Calcium sulfate ($CaSO_4$)	.0533	3.1132
Magnesium chlorid ($MgCl_2$)	11.2346	656.2130
Iron bicarbonate ($FeH_2(CO_3)_2$)	.1781	10.4029
Silica (SiO_2)	.0434	2.5349
Totals	86.1224	5030.4093

Analysis by E. H. S. Bailey and H. E. Davies.

48. Trans. Kans. Acad. Sci., vol. XV, pp. 86, 87.

The Seven Springs, Geuda Springs.

Lake above Geuda Springs.

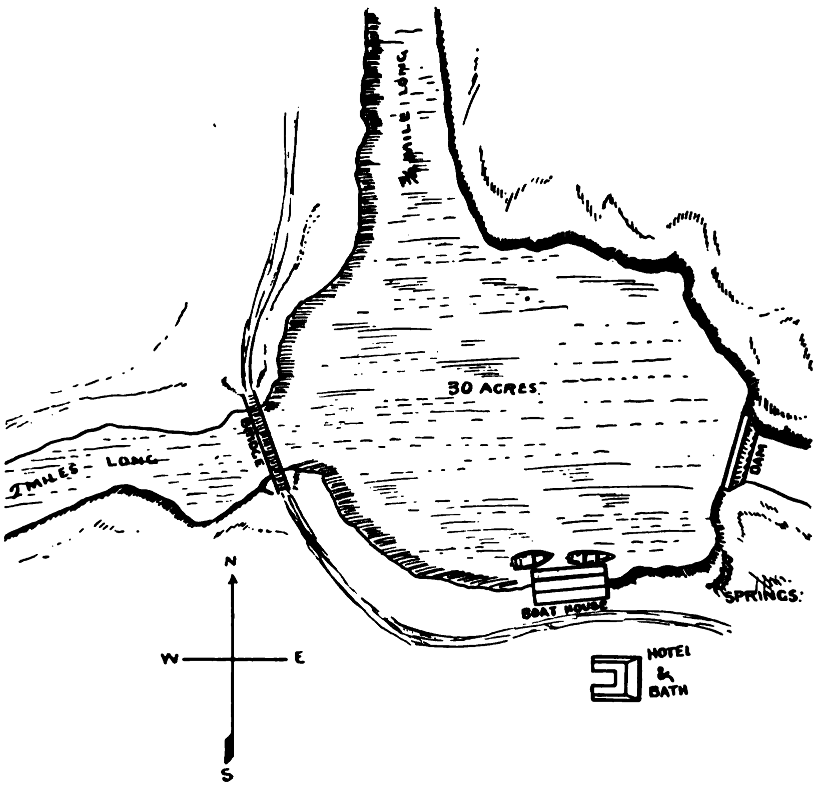
Geuda Springs.

In the south-central part of the state, on the line between Cowley and Sumner counties, is situated a remarkable group of springs that has been known since the earliest settlement of the state. These springs may be easily reached from Arkansas City, seven miles, by a branch of the St. Louis & San Francisco railroad. The town is only eight miles from the undulating plains of Indian Territory. It is about a mile from the Arkansas river, near its confluence with Slate creek. In the vicinity, especially to the north, there are numerous salt springs, so that many of the streams are quite saline in character. A small lake something more than a half-mile long and from five to ten rods wide, in the bed of the creek, was for some time used for boating and fishing. This lake was some years ago artificially improved and enlarged by placing a dam across the creek, making a body of water covering probably fifty acres, the largest salt lake in the state or in the vicinity. On the shores of the lake the salt is crystallized out, and glistens in the sunlight like newly fallen snow. The name "Geuda" is said to come from the Indian word "Ge-u-da," meaning healing springs, and it is believed that this locality was a favorite camping-ground with the aborigines.

IMPROVEMENTS.

In the year 1886 and for a year or two following, many improvements were made about the town and springs by the Geuda Springs Town and Water Company. A commodious bath-house and hotel combined was built, capable of accommodating forty guests. The dam for the lake was raised, approaches to the springs were improved, drives were laid out, and trees planted. More recently, other improvements have been made, and it is proposed to connect the town with Arkansas City by an electric road.

The owners are building an addition to the bottling works and are putting in a gasoline-engine for pumping, etc., so that now the capacity of the plant is fifty cases of fifty bottles each per day. They also make lemon sour, ginger ale, and other



Salt Lake, Geuda Springs.

carbonated beverages, which are shipped to points in Kansas and adjacent states.

On the high land west of the springs a beautiful and far-extending view of the vicinity may be obtained, with the village, hotels and stream in the foreground, and in the background the valley of the Arkansas, fading away toward the rich grazing lands of the Territory. The mineral springs at the north end of the principal street are unique in their situation and their properties. They are located in a space not more than twenty-five by thirty-two feet in area, and afford, at all times of the year, an abundant supply of clear water. The flow of each spring is from 100 to 450 gallons per hour. The waters are all brought above the surface by means of large earthen pipes cemented to the rock below, and the overflow is brought out in a series of parallel pipes, as shown in the cut, into a common waste-pipe which carries away quite a stream from the combined waters. The composition of the water, with the temperature and specific gravity, is given below.

Something over two years ago a dam with flume outlet was built across the "salt" depression directly north of the springs, and this caused the whole of the salt marsh to be covered with water, besides backing the water up the creek about two miles, and up the north arm of Salt marsh about three-quarters of a mile. This gives excellent boating for about three-quarters of a mile north and over one and one-quarter miles west from the boat-house. The lake, which, with its arms, covers about fifty acres, in dry seasons becomes quite salty, but the west arm, being a creek, in time of high water flows into the main body of the lake and over the dam, thus leaving mostly fresh water in the lake. This lake presents quite an attraction for boating and bathing. It has also been well stocked with fish.

Hotel Geuda.

Central Hotel and Bath-house, Geuda Springs.

Geuda Springs No. 1.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	6.9452	Sodium oxid (Na_2O)	9.3899
Potassium (K)	.0163	Potassium oxid (K_2O)	.0196
Lithium (Li)	trace	Lithium oxid (Li_2O)	trace
Calcium (Ca)	1.0230	Calcium oxid (CaO)	1.4322
Magnesium (Mg)	.1599	Magnesium oxid (MgO)	.2655
Iron (Fe)	.0004	Iron oxid (FeO)	.0006
Aluminum (Al)	.0006	Aluminum oxid (Al_2O_3)	.0011
Chlorin (Cl)	10.9284	Chlorin (Cl)	10.9284
Bromin (Br)	.0003	Bromin (Br)	.0003
Iodin (I)	trace	Iodin (I)	trace
Sulfuric acid ion (So_4)	2.8121	Sulfuric anhydrid (SO_3)	2.3225
Phosphoric acid ion (PO_4)	.0003	Phosphoric anhydrid (P_2O_5)	.0002
Nitric acid ion (NO_3)	.0051	Nitric anhydrid (N_2O_5)	.0045
Boric acid ion (B_4O_7)	.0021	Boric anhydrid (B_4O_6)	.0020
Silicic acid ion (SiO_3)	.0131	Silicic anhydrid (SiO_2)	.0104
		Carbonic anhydrid (CO_2)	.0399
		Water (H_2O)	.0080
		Oxygen equivalent	2.4687
		Total	21.9564

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	17.6793	1032.6479
Sodium phosphate (Na_3PO_4)	.0004	.0237
Sodium bromid (NaBr)	.0004	.0237
Sodium iodid (NaI)	trace	trace
Sodium nitrate ($NaNO_3$)	.0066	.3860
Sodium bicarbonate ($NaHCO_3$)	.0071	.4155
Sodium biborate ($Na_2B_4O_7$)	.0029	.1693
Potassium sulfate (K_2SO_4)	.0364	2.1261
Lithium chlorid (LiCl)	trace	trace
Calcium sulfate ($CaSO_4$)	3.4233	199.9549
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.0653	3.8141
Magnesium sulfate ($MgSO_4$)	.4383	25.6011
Magnesium chlorid ($MgCl_2$)	.2836	16.5650
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0013	.0759
Alumina (Al_2O_3)	.0011	.0642
Silica (SiO_2)	.0104	.6074
Organic matter	trace	trace
Totals	21.9564	1282.4733

Free carbon dioxid	34.956 cu. in.
Free hydrogen sulfid	1.018 cu. in.
Specific gravity	1.018
Temperature	17.3° C. (63.25° F.)

Analysis by E. H. S. Bailey and E. C. Franklin.

Geuda Springs.

	No. 2.		No. 3.	
	Grams per liter.	Grains per gallon.	Grams per liter.	Grains per gallon.
Sodium chlorid ($NaCl$)	18.1122	1057.9336	13.9865	816.9514
Sodium phosphate (Na_3PO_4)	.0004	.0233	.0004	.0233
Sodium bromid ($NaBr$)	.0004	.0233	.0004	.0233
Sodium iodid (NaI)	trace	trace	trace	trace
Sodium nitrate ($NaNO_3$)	.0070	.4088	.0031	.1810
Sodium bicarbonate ($NaHCO_3$)	.0055	.3215	.0077	.4500
Sodium biborate ($Na_2B_4O_7$)	.0029	.1691	.0029	.1692
Potassium sulfate (K_2SO_4)	.0289	1.6880	.0327	1.9100
Lithium chlorid ($LiCl$)	trace	trace	trace	trace
Calcium sulfate ($CaSO_4$)	3.5107	205.0599	2.8734	167.8075
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.1013	5.9169	.1028	6.0045
Magnesium sulfate ($MgSO_4$)	.4157	4.2810	.4893	28.5800
Magnesium chlorid ($MgCl_2$)	.3424	19.9995	.1717	10.0289
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0030	.1752	.0013	.0759
Alumina (Al_2O_3)	.0003	.0175	....	....
Silica (SiO_2)	.0148	.8650	.0140	.8172
Organic matter	trace	trace	trace	trace
Sodium sulfid ($NaHS$)	....	....	....	....
Total	22.5455	1316.8826	17.6862	1033.0510
Free carbon dioxid (cu. in.)	27.692	....	18.917	....
Specific gravity	1.016	....	1.012	....

Geuda Springs.

No. 4.		No. 5.		No. 6.		No. 7.	
Grams per liter.	Grains per gallon.	Grams per liter.	Grains per gallon.	Grams per liter.	Grains per gallon.	Grams per liter.	Grains per gallon.
11.5186	672.8014	6.1397	358.6198	7.4112	432.8882	8.6460	505.0128
.0005	.0292	.0007	.0408	.0004	.0233	.0014	.0818
trace	trace	....	....	....	....	....	....
trace	trace	....	....	....	....	....	....
....	....	.0005	.0292	.0006	.0354	.0006	.0350
.0119	.6950	.0084	.4906	.0053	.3095	.0103	.6016
.0015	.0876	.0022	.1285	.0022	.1285	.0043	.2510
.0327	1.9100	.0142	.8294	.0093	.5432	.0082	.4789
trace	trace	trace	trace	trace	trace	trace	trace
2.7145	158.5539	2.5010	146.0834	2.5247	147.4677	2.7466	160.4289
.1176	6.8694	.1832	10.7007	.2144	12.5231	.0946	5.5255
.4569	26.6875	.4284	25.0228	.4189	24.4679	.3921	22.9025
.1354	7.9087	.1449	8.4636	.0850	4.9648	.1658	9.6843
.0010	.0584	.0007	.0408	.0010	.0584	.0015	.0874
.0158	.9228	.0002	.0116	....	....	.0002	.0116
.0136	.7943	.0136	.7943	.0126	.7359	.0137	.8010
trace	trace	trace	trace	trace	trace	trace	trace
....	....	....	....	.0110	.6425	....	....
15.0200	877.3182	9.4377	551.2555	10.6966	624.7884	12.0853	705.9023
17.642	....	23.983	....	22.158	....	29.040	....
1.012	....	1.009	....	1.009	....	1.009	....

Analyses by E. H. S. Bailey and E. C. Franklin.

View East from Bridge, Geuda Springs.

Sanitarium at Independence.

Bromo-magnesium Well, Independence.

In 1884 a well 1100 feet deep was bored in the northern part of Independence, Montgomery county, The tube extends 400 feet from the surface, and a pipe used for drawing the water extends several hundred feet further into the well. The well is artesian in character, as a small stream flows from it most of the time. Independence is on the lines of the A. T. & S. F. and the Missouri Pacific railroads.

IMPROVEMENTS.

A sanitarium and bath hotel have been erected here, with seven bath-rooms, and facilities for using brine either directly or mixed with fresh water. The water is raised to the surface by windmill power. As will be noticed by the analysis which is given below, the well is interesting as containing a comparatively large quantity of bromids. It was the first water of this kind discovered in this region. Others have been found recently to contain bromids and iodids. A comparison of this water with some other well-known waters will be of interest:

	Fabian, N. Y.	Hawthorne, Saratoga.	Congress, Saratoga.	Dead Sea.	Bromo-magnesium well.
Sodium bromid (NaBr)....	4.655	1.534	8.559	156.53	13.711
Sodium iodid (KI).........	.235	.198	.138	trace	.092

Comparing this well with the water of the Atlantic ocean, it is seen to be somewhat similar in composition, though the Independence water contains a larger quantity of calcium salts, twice as much magnesium, more sodium iodid, and nearly one-half as much sodium bromid. The mineral strength of this water is about twice as great as ocean water, as may be seen from the following analysis:

BROMO-MAGNESIUM WELL, INDEPENDENCE.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	23.4678	Sodium oxid (Na_2O)	31.6278
Potassium (K)	.1060	Potassium oxid (K_2O)	.1279
Calcium (Ca)	2.7620	Calcium oxid (CaO)	3.8710
Magnesium (Mg)	1.5095	Magnesium oxid (MgO)	2.5159
Iron (Fe)	.0090	Iron oxid (FeO)	.0117
Aluminum (Al)	trace	Aluminum oxid (Al_2O_3)	trace
Chlorin (Cl)	45.0811	Chlorin (Cl)	45.0811
Bromin (Br)	.1826	Bromin (Br)	.1826
Iodin (I)	.0013	Iodin (I)	.0013
Sulfuric acid ion (SO_4)	.2395	Sulfuric anhydrid (SO_3)	.1995
Silicic acid ion (SiO_3)	.0251	Silicic anhydrid (SiO_2)	.0198
		Organic matter	trace
		Carbonic anhydrid (CO_2)	.2998
		Water (H_2O)	.0610
		Oxygen equivalent	10.1993
		Total	73.8001

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	59.4476	3472.433
Sodium bromid (NaBr)	.2351	13.733
Sodium iodid (NaI)	.0016	.093
Potassium sulfate (K_2SO_4)	.2361	13.793
Calcium chlorid ($CaCl_2$)	7.1872	419.806
Calcium sulfate ($CaSO_4$)	.1551	9.061
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.5236	30.586
Magnesium chlorid ($MgCl_2$)	5.9651	348.323
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0289	1.684
Alumina (Al_2O_3)	trace	trace
Silica (SiO_2)	.0198	1.157
Organic matter	trace	trace
Totals	73.8001	4310.669

Specific gravity 1.052

Temperature .... 16.6° C. (62° F.)

Analysis by E. H. S. Bailey.

Lawrence, Douglas County, Artesian Well.

Several years ago a well was bored on the bank of the Kaw river, northeast of the Santa Fe railroad depot, for the purpose of testing the underlying strata. After it reached the depth of about 1400 feet, the boring was abandoned. A small stream of salt water continually runs from this well. This water is used locally with good results for rheumatism, etc. This water has the following composition:

LAWRENCE ARTESIAN WELL.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	4.2160	Sodium (Na_2O)	5.6898
Calcium (Ca)	2.7924	Calcium oxid (CaO)	3.9144
Magnesium (Mg)	6.3096	Magnesium oxid (MgO)	10.5160
Iron (Fe)	.0481	Iron oxid (FeO)	.0619
Chlorin (Cl)	30.0656	Chlorin (Cl)	30.0656
Bromin (Br)	trace	Bromin (Br)	trace
Silicic acid ion (SiO_3)	.1076	Silicic anhydrid (SiO_2)	.0852
		Carbonic anhydrid (CO_2)	.0757
		Water (H_2O)	.0154
		Oxygen equivalent	6.7945
		Total	43.6295

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	10.7147	625.845
Sodium bromid (NaBr)	trace	trace
Calcium chlorid ($CaCl_2$)	7.5712	452.748
Magnesium chlorid ($MgCl_2$)	24.9254	1455.893
Iron bicarbonate ($FeH_2(CO_3)_2$)	.1530	8.937
Silica (SiO_2)	.0852	4.976
Totals	43.6295	2548.400

Temperature .... 18.5° C. (65.5° F.)
Specific gravity 1.0355

Analysis by E. Bartow and H. M. Thompson.

Leavenworth Natatorium, Leavenworth County.

A natatorium has been established on Third street and Metropolitan avenue, near the United States military reservation, by the Home-Riverside Coal-mining Company, to utilize the waters from their mines. These mines are about 750 feet deep, and the salt water or "ocean spray" is pumped from this depth. The pump for this water has a two-inch discharge and is run from four to six hours per day, to pump the water into cisterns, and from thence to the natatorium.

The building is 41 x 100 feet, with dressing-rooms 15 x 40 feet and 6 x 100 feet. There is a swimming pool 30 x 75 feet, with a depth of from 2 to 7 feet. This place is operated more as a resort than for medical or cleansing purposes. There is such an abundance of water as to admit of a continuous flow through the pool. This natatorium is in operation during the summer months, and last season served about 6000 people.

"OCEAN SPRAY" (MINE WATER), HOME-RIVERSIDE COAL-MINING COMPANY, LEAVENWORTH.

IONS.	Grams per liter.
Sodium (Na)	9.2962
Calcium (Ca)	.5412
Magnesium (Mg)	.2315
Iron (Fe)	.0084
Chlorin (Cl)	15.7171
Sulfuric acid ion (SO_4)	.0362
Silicic acid ion (SiO_3)	.0548

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	23.6065	1378.86
Calcium chlorid ($CaCl_2$)	1.1753	68.66
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.3386	19.78
Magnesium chlorid ($MgCl_2$)	.8793	51.36
Magnesium sulfate ($MgSO_4$)	.0453	2.65
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0267	1.56
Silica (SiO_2)	.0426	2.49
Totals	26.1143	1525.36

Analysis by O. F. Stafford.

Marion Mineral Well.

The city of Marion and vicinity is rich in springs, some of which are strongly impregnated with mineral matter. The city is on the line of the A. T. & S. F. railway, and also on the C. R. I. & P. In the northern part of the city, three blocks from the Elgin hotel, a commodious three-story stone building was erected, and used as a sanitarium and bath-house. This was formerly managed in connection with a deep well. This well is about fifty feet from Luta creek, one of the streams that unite to form the Cottonwood river, just below the city. The well was drilled as a prospect hole, and is 175 feet deep, and has connected with it two pumps, one taking the water from a depth of fifty feet, at a point just above the rock, and the other taking the water from a point twenty-five feet above the bottom. Both waters contain hydrogen sulfid (H_2S) when first drawn. The upper water is utilized for drinking and the other for bathing purposes. The analysis given below shows an important difference between these two waters. The upper water is a saline water while the lower is a concentrated brine stronger even than sea water. For analysis of upper vein, see chapter XII.

[48]MARION WELL (LOWER VEIN).

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	22.4131	Sodium oxid (Na_2O)	31.6871
Calcium (Ca)	.9898	Calcium oxid (CaO)	1.3858
Magnesium (Mg)	.4663	Magnesium oxid (MgO)	.7772
Iron (Fe)	.0031	Iron oxid (FeO)	.0038
Chlorin (Cl)	33.1232	Chlorin (Cl)	33.1232
Sulfuric acid ion (SO_4)	8.3932	Sulfuric anhydrid (SO_3)	6.9946
Silica (SiO_2)	.0128	Silica (SiO_2)	.0128
Organic matter	trace	Carbonic anhydrid (CO_2)	.0046
		Water (H_2O)	.0009
		Oxygen equivalent	7.4854
		Total	66.5046

Analysis by E. H. S. Bailey.

48. Trans. Kan. Acad. Sci., vol. XII, p. 26.

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium sulfate (Na_2SO_4)	6.1427	358.7951
Sodium chlorid (NaCl)	54.6433	3191.6851
Calcium sulfate ($CaSO_4$)	3.3648	196.5379
Magnesium sulfate ($MgSO_4$)	2.3316	136.1887
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0094	.5491
Silica (SiO_2)	.0128	.7476
Totals	66.5046	3884.5035

Mound City Well, Linn County.

No. 1.

There is a salt well on the property of Doctor Trego, at Mound City. This well, which is 340 feet deep, was bored with an eight-inch drill. The brine comes into the well at a depth of 210 feet, and is forced out at the top of the well by the gas which accompanies it. Since 1886, when the well was bored as a prospect hole, the water has been flowing at the rate of about forty gallons per hour. The brine is used locally for medicinal purposes. This water yields 1020 grains of mineral matter to the gallon, upon evaporation. Of this, 1000 grains is common salt. The reaction of the water is slightly alkaline. Besides the salt, it contains small quantities of sodium carbonate, calcium carbonate, and magnesium carbonate, as well as traces of sulfates, bromids, and iodids.

No. 2.

Another salt well, about 400 feet from No. 1, on the property of Robert Fleming, has been recently bored, to the depth of 144 feet, and it has about the same flow as the former. This, as well as the former well, showed thirty-five pounds per square inch of gas pressure. The water is a brine, not as salt as No. 1, however. It contains 719 grains of mineral matter per gallon, and of this, 686 grains is common salt. The other ingredients are carbonates of iron, calcium, magnesium, and sodium, rather more in proportion than No. 1.

Mound Valley, Labette County, Salt Well.

At Mound Valley is a salt well 600 feet deep, the water from which was formerly used in a health home near by, which was built to utilize the water. As it has not been extensively advertised, its use does not extend beyond the immediate vicinity. The water gushes out of the top of the well with sufficient force so that it can be piped to the hotel. The home is pleasantly situated a short distance east of the village, and the latter is easily accessible by two lines of railroad. It has been proposed to utilize the gas that comes up with the water for heating purposes. There are other gas wells in the vicinity which yield gas for local consumption, but the pressure is not very great.

Overbrook, Osage County, Well.

ATCHISON WELL.

There is a well two and one-half miles northwest of the town on the farm of John Atchison. The water has been recommended by some of the local physicians on account of its therapeutic properties. The well is 180 feet deep.

OVERBROOK, ATCHISON WELL.

Grams per liter.

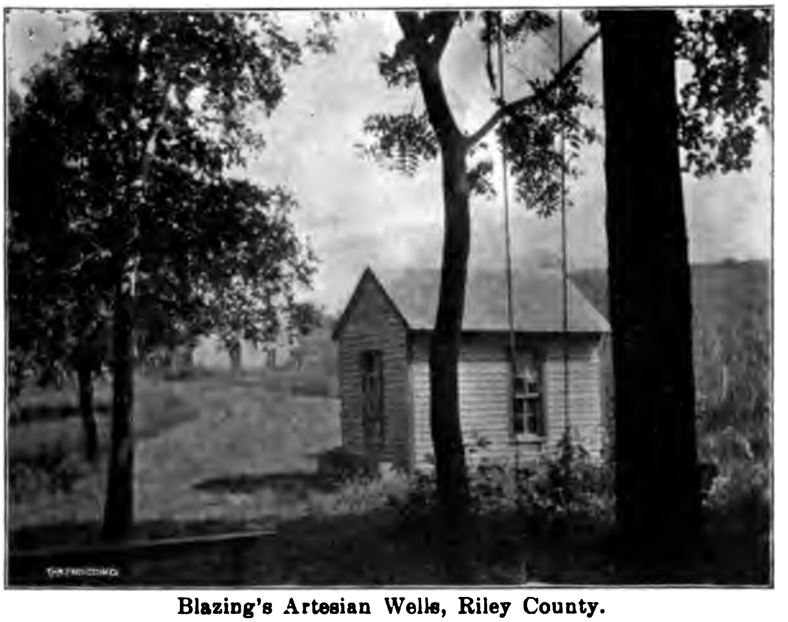
IONS.		RADICALS.	
Sodium (Na)	4.0502	Sodium oxid (Na_2O)	5.4572
Calcium (Ca)	.1248	Calcium oxid (CaO)	.1773
Magnesium (Mg)	.0817	Magnesium oxid (MgO)	.1361
Iron (Fe)	.0515	Iron oxid (FeO)	.0663
Chlorin (Cl)	6.2398	Chlorin (Cl)	6.2398
Sulfuric acid ion (SO_4)	.3298	Sulfuric anhydrid (SO_3)	.2745
Silicic acid ion (SiO_3)	.3072	Silica (SiO_2)	.2429
		Carbonic anhydrid (CO_2)	.3586
		Water (H_2O)	.0726
		Oxygen equivalent	1.4103
		Total	11.6150

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	10.2941	601.2413
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.5020	29.3218
Calcium sulfate ($CaSO_4$)	.0041	.2394
Magnesium sulfate ($MgSO_4$)	.4082	23.8488
Iron bicarbonate ($FeH_2(CO_3)_2$)	.1637	9.5640
Silica (SiO_2)	.2429	14.1877
Totals	11.6150	678.4030

Analysis by E. H. S. Bailey and Watson Sellards.

Geyser Mineral Bath-house, Rosedale.



Blazing's Artesian Wells, Riley County.

Geyser Mineral Well, Rosedale.

A well about 300 feet deep was bored here several years ago for the purpose of getting gas. Well is situated on the south side of the rather narrow valley of Turkey creek, just north of the stream, at a point where it runs close to the high bluffs on the south. The water is pumped from the well and stored in large wooden tanks in the second story of the building.

IMPROVEMENTS.

A few years ago a bathing establishment was erected here, and it receives good patronage. The bath-house is divided into two sections, so as to accomodate both men and women. There are about a dozen bath-rooms, with cots for resting or sleeping in adjacent rooms.

There is a sufficient quantity of gas arising from the well, so that it is stored in tanks and used for running a gas-engine for pumping the water. The gas is also burned under the boiler for generating steam for heating purposes. There is sufficient gas in the water so that it effervesces like soda-water, and if the stopper be taken out of a bottle that has been nearly filled with water, the gas may be lighted at the mouth. The gas has practically no odor, and the water gives no reaction for hydrogen sulfid. This mineral spring company also manufactures "pop" and effervescent drinks from ordinary water.

GEYSER MINERAL WELL, ROSEDALE, JOHNSON COUNTY.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	9.1991	Sodium oxid (Na_2O)	12.3977
Calcium (Ca)	.2975	Calcium oxid (CaO)	.4164
Magnesium (Mg)	.1890	Magnesium oxid (MgO)	.3155
Barium (Ba)	.0193	Barium oxid (BaO)	.0216
Strontium (Sr)	.0020	Strontium oxid (SrO)	.0024
Aluminum (Al)	.0095	Aluminum oxid (Al_2O_3)	.0178
Iron (Fe)	.0032	Iron oxid (FeO)	.0042
Chlorin (Cl)	14.1400	Chlorin (Cl)	14.1400
Bromin (Br)	.0260	Bromin (Br)	.0260
Iodin (I)	.0010	Iodin (I)	.0010
Silicic acid ion (SiO_3)	.0139	Silicic anhydrid (SiO_2)	.0110
		Carbonic anhydrid (CO_2)	1.3698
		Water (H_2O)	.2822
		Oxygen equivalent	3.1981
		Total	25.8075

Hypothetically combined as follows:

	Grams per liter.	Grains. per gallon.
Sodium chlorid (NaCl)	23.3362	1363.067
Sodium bromid (NaBr)	.0334	1.951
Sodium iodid (NaI)	.0012	.070
Calcium bicarbonate ($CaH_2(CO_3)_2$)	1.2046	70.361
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	1.1516	67.265
Barium bicarbonate ($BaH_2(CO_3)_2$)	.0365	2.132
Strontium bicarbonate ($SrH_2(CO_3)_2$)	.0048	.280
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0104	.607
Alumina (Al_2O_3)	.0178	1.040
Silica (SiO_2)	.0110	.643
Totals	25.8075	1507.416

Specific gravity 1.018
Temperature .... 15.5° C. (60° F.)

Analysis by E. H. S. Bailey.

Saint Paul, Neosho County.

A well 700 feet deep was bored at this place. The well is located on the second bottom of the Neosho river and produces considerable gas, which bubbles up with the water.

[49] SAINT PAUL DEEP WELL.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	10.8198	Sodium oxid (Na_2O)	14.5554
Calcium (Ca)	.4652	Calcium oxid (CaO)	.6514
Magnesium (Mg)	.3410	Magnesium oxid (MgO)	.5684
Iron and aluminum (Fe and Al),	.0498	Iron and aluminum oxids (Al_2O_3 and Fe_2O_3)	.0640
Chlorin (Cl)	17.1240	Chlorin (Cl)	17.1240
Sulfuric acid ion (SO_4)	.0224	Sulfuric anhydrid (SO_3)	.0187
Silicic acid ion (SiO_3)	.0215	Silicic anhydrid (SiO_2)	.0170

Temperature .... 12.7° C. (55° F.)

Analysis by E. H. S. Bailey and H. E. Davies.

49. Trans. Kan. Acad. Sci., vol. XV, p. 87.

COMPARISON OF SIMILAR WATERS.

Waters of the chlorine group or brines are common in very many parts of the world. For comparison, it is of interest to notice the analysis of some typical waters in the United States and abroad ; the results in all cases are expressed in grains per gallon.

Sulpho-magnesium Well, Excelsior Springs, Mo.

Analysis by E. H. S. Bailey.

Sodium chlorid	644.554	Calcium bicarbonate	49.768
Sodium bromid	1.050	Magnesium bicarbonate	5.686
Sodium iodid	0.840	Magnesinm sulfate	23.566
Sodium bicarbonate	1.994	Iron bicarbonate	0.869
Sodium hydrosulfid	0.192	Silica	0.647
Sodium sulfate	5.248	Total	735.790
Potassium sulfate	1.376		

Carbon-dioxid gas, abundant.
Hydrogen sulfid gas, a trace.

Moorman's Mineral Well, Yypsilanti, Mich.

Analysis by F. M. Shepard.

Sodium chlorid	1,573.62	Magnesium chlorid	128.09
Sodium sulfid	8.42	Magnesium bromid	10.97
Potassium sulfate	35.33	Magnesium sulfate	103.76
Calcium sulfate	175.65	Silica	19.81
Calcium carbonate	57.26	Total	2,256.26
Calcium chlorid	143.35		

Hydrogen-sulfid gas, 26.84 cubic inches.

Upper Blue Lick Springs, Nicholas County, Kentucky.

Analysis by T. F. Fudge and A. Fennel.

Sodium chlorid	516.53	Magnesium chlorid	37.72
Potassium chlorid	1.80	Magnesium carbonate	0.14
Potassium sulfate	12.97	Alumina, lime phosphate, iron peroxid	1.96
Calcium carbonate	25.06	Silica	1.00
Calcium sulfate	44.13	Loss on ignition	14.88
Magnesium bromid	3.80	Totals	660.14
Magnesium iodid	0.15		

Carbon-dioxid gas .... 48.16 cubic inches.
Hydrogen-sulfid gas .... 8.16 " "

Harrowgate, England. "Montpelier," Strong.

Analyzed by A. W. Hoffman.

Sodium chlorid	642.472	Calcium chlorid	49.528
Sodium sulfid	11.528	Magnesium chlorid	43.736
Potassium chlorid	4.600	Silica	1.472
Calcium carbonate	19.344	Total	773.152
Calcium sulfate	0.472		

Carbon-dioxid gas	11.208 cubic inches.
Oxygen gas	0.384 " "
Nitrogen gas	3.856 " "
Marsh gas	0.424 " "

Kreuznach, Oranienquelle, Rhenish Prussia.

Analyzed by Liebig.

Sodium chlorid	869.640	Magnesium iodid	0.096
Potassium chlorid	3.680	Ferrous carbonate	2.848
Calcium carbonate	2.040	Aluminum phosphate	0.760
Calcium chlorid	181.992	Silica	7.992
Magnesium carbonate	1.040	Total	1,084.328
Magnesium bromid	14.240		

Comparison of Abilene Artesian Well with some other Waters.

	Atlantic ocean.	Dead Sea.	Hutchinson brine.	Abilene artesian well.	Bromo-magnesium well.
Sodium chlorid	1671.34	6702.73	15978.640	8352.456	3472.433
Potassium chlorid		682.63			
Ammonium chlorid		3.35			
Calcium chlorid		1376.75	13.200	1396.408	419.806
Magnesium chlorid	199.66	4457.23	143.105	635.909	348.323
Aluminum chlorid		31.37			
Iron chlorid		1.50		12.219	
Iron bicarbonate					1.684
Manganese chlorid		3.35			
Sodium bromid	31.16	156.53		38.743	13.733
Potassium sulfate	108.46				13.793
Magnesium sulfate	34.99				
Calcium sulfate	93.30	38.07	341.990	10.327	9.061
Sodium iodid				0.432	0.093
Calcium bicarbonate					30.586
Organic matter		34.59			trace
Insoluble residue			1.460	0.525	1.157
Totals	2138.91	13488.10	16478.395	10447.019	4310.669
Specific gravity	1.0275	1.172		1.112	1.052

Comparison of the Most Important Constituents of the Waters of the *Chlorid* Group.

Grains per gallon.

Name.	Total solids.	Sodium chlorid.	Calcium chlorid.	Calcium bicar-bonate.	Calcium sulfate.	Magnesium chlorid.	Magnesium sulfate.
Abilene artesian	10447	8352	1396	....	10	365	....
Arkansas City	3131	1809	....	....	60	....	75
Laundry, Atchison	88	71	....	5	1	....	....
Prospect, Atchison	1655	1451	....	130	1	....	....
Becker's, Atchison	1711	1495	....	2	81	....	....
Eureka	492	400	....	11	42	18	....
Fredonia	5030	4118	230	....	3	656	....
Geuda, No. 1	1282	1032	....	3	199	16	25
Bromo-magnesium	4310	3472	419	30	9	348	....
Ocean Spray	1525	1378	68	19	....	51	2
Marion	3884	3191	....	....	196	....	136
Overbrook	678	601	....	29	....	....	23
Geyser	1507	1363	....	70	....	....	....
Excelsior Springs, Mo.	735	644	....	49	....	....	23
Ypsilanti, Mich.	2256	1573	143	* 57	175	128	103
Blue Lick, Ky.	660	516	....	* 25	44	37	....
Harrowgate, England	773	642	49	19	....	43	....
Kreuznach, Germany	1084	869	181	2	....	....	....

* Calcium chlorid.

These waters are evidently of different degrees of dilution, although common salt is a characteristic ingredient of all of them. Calcium salts are also present in most of them, although represented in various combinations. Calcium sulfate, as would be expected when we consider the origin of the waters from evaporated ocean water, is usually present. When the magnesium salt is not reported as chlorid or sulfate, magnesium bicarbonate is usually considered as being present. It is of interest to notice that iron bicarbonate, sometimes as much as eleven grains in a gallon, is found in these waters. The same thing is noticed in the saturated brines that are pumped up for the manufacture of salt. When these waters are used internally, it is evident that the iron salts present must have an important influence on the system.

The Arkansas City water is reported as containing 171 grains of sodium sulfate per gallon, so it would have the added properties of this cathartic salt. The Marion well is still richer in this substance, as it contains 358 grains per gallon. The presence of bromids and iodids in many of the chlorid waters has already been referred to, and, indeed, calls for a classification sometimes in the special group.

A glance at the table will show that the Kansas waters compare favorably in quantity of constituents and in variety with waters of the same class found elsewhere.

CHAPTER XI.

The Sulfate Group.

The sulfates are extremely common in mineral waters. Under the familiar name of "salts" or "Epsom salts" we have magnesium sulfate, and under the name of "Glauber's salts" we have sodium sulfate. Calcium sulfate, which is soluble in water to the extent of 1 part in 380 parts of cold water, is also often found, as is a small quantity of potassium sulfate, a substance much like sodium sulfate in its properties.

These are often called "purgative waters," on account of their marked action on the bowels, and as they are, if concentrated, of a bitter-sweet taste, they are also called "bitter waters." The name Epsom is derived from the name of the purging well at Epsom or Ebbesham, near London, once a very popular water.

In regard to water of this class, Doctor Schweitzer says:[50] "Dolomitic limestones and limestones containing gypsum produce the Epsom and Glauber's salt springs; magnesium sulfate and calcium carbonate resulting from their interaction, the former of which is very soluble and constitutes the main ingredient of the Epsom salt springs or wells. Such waters are nearly all obtained from wells or shafts, sometimes only ten or twenty feet deep. They contain, in addition, variable amounts of other sulfates but rarely chlorids or carbonates. If the limestone above mentioned were associated with marls rich in alkalies, or with other rocks containing alkaline carbonates or silicates, the conditions are given for the formation of Glauber's salt springs. These may be alkaline or neutral, as sodium carbonate or magnesium sulfate happens to be in excess.

50. Missouri Geological Survey, vol. III, p. 5.

They are usually of more varied composition than are the Epsom salt wells."

Kansas is particularly rich in waters of this class; some of them are heavily loaded with mineral constituents, especially sodium and magnesium sulfate, and there is another class having relatively larger quantities of calcium sulfate. While the former are nearly all from wells, the calcium-sulfate waters are frequently derived from springs.

This group is represented by the following waters:

Abilena, Dickinson county.
Ball's well, Cherokee county.
Blasing's artesian wells, Riley county.
Burr Oak, Jewell county.
Capioma, Nemaha county.
Cave Springs, Cherokee county.
Carbondale, Osage county.
Centralia, Nemaha county.
Chico Springs, Cherokee county.
Conway, McPherson county.
Council Grove, Morris county.
Fagan, Graham county.
Marion, Marion county, lower vein.
Marion (Chingawassa Springs), Marion county.
Madison, Greenwood county, magnesium well.
Neuchatel, Nemaha county.
Parsons, Labette county.
Stotler, Lyon county.
Sun Springs, Brown county, Nos. 2, 3, and 4.
Sycamore Springs, Brown county, Nos. 1 and 2.
Victoria, Ellis county.
Walton, Harvey county.
White Rock, Jewell county.
Williamsburg, Franklin county.

Abilena Wells, Abilene, Dickinson County.

In the summer of 1897 a well was drilled on a ridge of high land in the northeast quarter of section 4, township 12, range 1 east, in Dickinson county, about fourteen miles northwest of Abilene. This well was drilled for stock purposes by Mr. M. P. Jolley, agent for the Travelers' Insurance Company. It is ninety-five feet in depth, and passes through a hard rock, into various formations of interesting character. The yield from this one well is said to be about six barrels per day. The water is clear when pumped, and if exposed to cold deposits beautiful crystals. The temperature varies somewhat, as at one time it was 12.2° C. (54° F.), while at another it was 19° C. (66° F.) There is a six-inch casing nearly to the bottom of the well, and the water is raised by an ordinary lift-pump. Two other wells were bored in the summer of 1901; No. 2 having a depth of 120 feet, and No. 3 having a depth of 85 feet. The water in No. 2 had the greatest specific gravity, No. 1 next, and the water of No. 3 was the weakest. Thus it is seen that the deepest well yields the strongest water. Later No. 1 and No. 3 were put down to a depth of 130 feet, and three other wells were drilled to the same depth; so all are now said to produce water of a uniform strength. In addition to these, a dug well, six feet in diameter, has been put down within ten feet of No. 2 to a depth of 120 feet, and is seventeen feet across at the bottom, thus furnishing great storage capacity. These wells and other improvements are the result of the purchase of the property in 1900 by the Abilena Company. The water was put upon the market by the company under the name of "Abilena." The water is hauled from the wells to the bottling plant in Abilene. The only treatment it receives is a careful filtration through sand and charcoal, to remove a small quantity of suspended matter. In order to be supplied with the best modern equipment and increased storage facilities, the company is now erecting a large bottling plant and warehouses on property recently bought for that purpose.

ABILENA WELLS.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	22.6112	Sodium oxid (Na_2O)	30.4734
Potassium (K)	.7998	Potassium oxid (K_2O)	.9714
Calcium (Ca)	.4980	Calcium oxid (CaO)	.6993
Magnesium (Mg)	.2997	Magnesium oxid (MgO)	.4995
Iron (Fe)	.0032	Iron oxid (FeO)	.0040
Chlorin (Cl)	.3565	Chlorin (Cl)	.3565
Nitrate ion (NO_3)	.0040	Nitric anhydrid (N_2O_5)	.0034
Sulfuric acid ion (SO_4)	49.2302	Sulfuric anhydrid (SO_3)	41.0259
Silicic acid ion (SiO_3)	.0199	Silicic anhydrid (SiO_2)	.0157
		Carbonic anhydrid (CO_2)	.7594
		Water (H_2O)	.1557
		Oxygen equivalent	.0805
		Total	74.8837

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.5883	34.3626
Sodium sulfate (Na_2SO_4)	68.7473	4015.5297
Sodium bicarbonate (Na_4HCO_3)	.3548	20.7238
Potassium sulfate (K_2SO_4)	1.7970	104.9627
Potassium nitrate (KNO_3)	.0064	.3738
Calcium sulfate ($CaSO_4$)	.8178	47.7677
Calcium bicarbonate ($CaH_2(CO_3)_2$)	1.0479	61.2079
Magnesium sulfate ($MgSO_4$)	1.4985	87.5274
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0100	.5842
Silica (SiO_2)	.0157	.9171
Totals	74.8837	4373.9569

Specific gravity............ 1.065, at 15.5° C.
Temperature............... 12.2° C. (54° F.)

Analysis by E. H. S. Bailey.

Baxter Springs Mineral Well.

There is a well on the farm of A. T. Ball, one mile north of the town and one-half mile west of Spring river. The well is 37 feet deep, usually contains 15 feet of water, and is not greatly affected by surface-water. There is a great diversity in the character of the water of different wells in this vicinity, on account of the peculiar arrangement of the strata; indeed, in some cases, it is necessary to drill to a depth of 400 feet to obtain a permanent supply of water.

A qualitative analysis shows that the water contains sodium chlorid, calcium sulfate, iron and aluminum, magnesium sulfate, and a trace of potassium nitrate. It is evidently a cathartic water.

Blasing's Artesian Mineral Wells, near Manhattan.

These wells are situated in Zeandale township, ten miles southeast of Manhattan, in a well-wooded, rolling country. They were discovered in 1883 by William Blasing, while prospecting for coal or other "mineral." "The location of these wells is in the fork of two creeks, bordered with a belt of timber in the shape of a horseshoe. An oval hill rises within this belt of timber, and at the foot of this hill is well No. 1 (120 feet deep), on the south side, and well No. 2 (180 feet deep), on the north side, ten feet above the level of the bottom land. At the foot of the hill is a stone-quarry, and there is a farmhouse and hotel midway between the two wells." The water flows over the top of each of these wells. A single well is said to discharge 800 gallons per hour. The water was formerly delivered to customers in Manhattan, and also shipped from that point. The residue remaining after the water is evaporated was also sold under the name of "mineral." In connection with the wells there is a hotel containing bath-rooms, with hot and cold water, and arrangements for steam- and shower-baths. These wells may be reached by carriage from Zeandale on the C. R. I. & P., and from Manhattan on the C. R. I. & P. and the U. P. R. R.

BLASING'S MINERAL WELLS.[51]

No. 1.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0066	Sodium oxid (Na_2O)	.0089
Potassium (K)	trace	Potassium oxid (K_2O)	trace
Lithium (Li)	trace	Lithium oxid (Li_2O)	trace
Calcium (Ca)	.4736	Calcium oxid (CaO)	.6626
Magnesium (Mg)	.0581	Magnesium oxid (MgO)	.0969
Iron (Fe)	.0024	Iron oxid (FeO)	.0032
Chlorin (Cl)	.0251	Chlorin (Cl)	.0251
Bromin (Br)	trace	Bromin (Br)	trace
Sulfuric acid ion (SO_4)	1.2680	Sulfuric anhydrid (SO_3)	1.0558
Silicic acid ion (SiO_3)	.2191	Silicic anhydrid (SiO_2)	.1731
		Total	2.0256

No. 2.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0110	Sodium oxid (Na_2O)	.0148
Potassium (K)	trace	Potassium oxid (K_2O)	trace
Calcium (Ca)	.2552	Calcium oxid (CaO)	.3561
Magnesium (Mg)	.0678	Magnesium oxid (MgO)	.1130
Iron (Fe)	.0032	Iron oxid (FeO)	.0042
Chlorin (Cl)	.0308	Chlorin (Cl)	.0308
Sulfuric acid ion (SO_4)	.6810	Sulfuric anhydrid (SO_3)	.5679
Silicic acid ion (SiO_3)	.0041	Silicic anhydrid (SiO_2)	.0032
		Total	1.0900

Analyses by G. H. Failyer.

[52] Burr Oak, Jewell County.

A well at Burr Oak is reported as having the following composition:

Grams per liter.

Sodium (Na)	.3170	Sodium oxid (Na_2O)	.4270
Potassium (K)	trace	Potassium oxid (K_2O)	trace
Lithium (Li)	.0008	Lithium oxid (Li_2O)	.0017
Calcium (Ca)	.4623	Calcium oxid (CaO)	.6479
Magnesium (Mg)	.3748	Magnesium oxid (MgO)	.6250
Iron (Fe)	.0144	Iron oxid (FeO)	.0185
Aluminum (Al)	.0623	Aluminum oxid (Al_2O_3)	.1175
Chlorin (Cl)	.1051	Chlorin (Cl)	.1051
Sulfuric acid ion (SO_4)	2.9407	Sulfuric anhydrid (SO_3)	2.2620
Phosphoric acid ion (PO_4)	trace	Phosphoric anhydrid (P_2O_5)	trace
Boric acid ion (B_4O_7)	trace	Boric anhydrid (B_4O_6)	trace
Silicic acid ion (SiO_3)	.1117	Silicic anhydrid (SiO_2)	.0883

Analysis by G. H. Failyer and C. M. Breese.

51. Trans. Kan. Acad. Sci., vol. IX, pp. 114, 115.

52. Trans. Kan. Acad. Sci., vol. IX, p. 109.

Capioma Magnesium Well.

Near Capioma, Nemaha county, seven miles due south of Sabetha, on the farm of Philip Hackett, is a drilled well 130 feet deep. The first ninety feet was drilled in 1896, and the last forty feet in 1900. The well has a six-inch iron casing. On account of the peculiar taste, the attention of the owner was called to the water, and the analysis showed it to be a strong magnesium water, containing sodium sulfate. Sabetha is on the C. R. I. & P. railway and the St. Joseph & Grand Island railroad.

CAPIOMA WELL.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.4211	Sodium oxid (Na_2O)	.5698
Potassium (K)	trace	Potassium oxid (K_2O)	trace
Calcium (Ca)	.5420	Calcium oxid (CaO)	.7576
Magnesium (Mg)	.2195	Magnesium oxid (MgO)	.3655
Iron (Fe)	.0011	Iron acid (FeO)	.0014
Aluminum (Al)	.0055	Aluminum oxid (Al_2O_3)	.0103
Chlorin (Cl)	.3243	Chlorin (Cl)	.3243
Sulfuric acid ion (SO_4)	2.3500	Sulfuric anhydrid (SO_3.)	1.9577
Silicic acid ion (SiO_3)	.0216	Silica (SiO_2)	.0170
		Carbonic anhydrid (CO_2)	.2551
		Water (H_2O)	.0504
		Oxygen equivalent	.0732
		Total	4.2259

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.5344	31.2143
Sodium bicarbonate ($NaHCO_3$)	.0252	1.4719
Sodium sulfate (Na_2SO_4)	.6342	37.0436
Potassium sulfate (K_2SO_4)	trace	trace
Calcium sulfate ($CaSO_4$)	1.4780	86.3300
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.4270	24.9411
Magnesium sulfate ($MgSO_4$)	1.0965	64.0466
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0033	.1928
Aluminua (Al_2O_3)	.0103	.6016
Silca (SiO_2)	.0170	.9929
Totals	4.2259	246.8348

Analysis by E. H. S. Bailey.

Carbondale Mineral Springs.

In the vicinity of Carbondale, Osage county, and in the town there are a number of springs and wells strongly impregnated with mineral matter, and in many places this saline water is found by boring from 75 to 100 feet. The surface-water seems to be comparatively free from mineral salts, but if this is shut out by carefully casing a well, an abundant supply of mineral water is obtained. Numerous wells and springs are found on the western slope of the hill east of the city of Carbondale. Along the crest of this hill, at some distance east, there are many openings and "stripping banks," where coal has been mined for the last twenty-five years, but on account of the comparatively thin veins of coal it has not been found profitable to sink many shafts. The waters of Carbondale do not appear to be in any sense mine waters, although they are found below where the coal is mined, and at some distance away.

Carbondale is on the main line of the A. T. & S. F. railway.

North of the city about a mile and a half, on the direct road to Topeka, is the locality where the greatest improvements have been made. To the west of this road, upon a plateau slightly elevated above the valley to the south, a well about forty feet deep was sunk several years ago, and an inexhaustible supply of mineral water was obtained. Practically no improvements have been made in this property, although the water has been extensively used and also shipped abroad.

CARBONDALE SPRING.

Grams per liter.

IONS.		RADICALS.	
Ammonium (NH_4)	trace	Ammonia (NH_3)	trace
Potassium (K)	.0080	Potassium oxid (K_2O)	.0097
Sodium (Na)	.7228	Sodium oxid (Na_2O)	.9863
Calcium (Ca)	.0801	Calcium oxid (CaO)	.1121
Magnesium (Mg)	.0625	Magnesium oxid (MgO)	.0443
Iron (Fe)	.0004	Iron oxid (FeO)	.0005
Aluminum (Al)	.0051	Aluminum oxid (Al_2O_3)	.0096
Chlorin (Cl)	.7946	Chlorin (Cl)	.7946
Bromin (Br)	.0009	Bromin (Br)	.0009
Iodin (I)	.0005	Iodin (I)	.0005
Sulfuric acid ion (SO_4)	.4650	Sulfuric anhydrid (SO_3)	.3873
Phosphoric acid ion (PO_4)	.0001	Phosphoric anhydrid (P_2O_5)	.0001
Boric acid ion (B_4O_7)	.0098	Boric anhydrid (B_4O_6)	.0089
Silicic acid ion (SiO_3)	.0065	Silica (SiO_2)	.0051
		Carbonic anhydrid (CO_2)	.2638
		Water (H_2O)	.0542
		Oxygen equivalent	.1792
		Total	2.4983

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Ammonium sulfate ($(NH_4)_2SO_4$)	trace	trace
Potassium sulfate (K_2SO_4	.0179	1.0455
Sodium sulfate (Na_2SO_4)	.6442	37.6277
Sodium chlorid (NaCl)	1.3094	76.4820
Sodium phosphate (Na_3PO_4)	.0001	.0058
Sodium bicarbonate ($NaHCO_3$)	.0156	.9112
Sodium biborate ($Na_2B_4O_7$)	.0128	.7476
Sodium iodid (NaI)	.0006	.0354
Sodium bromid	.0012	.0700
Calcium sulfate ($CaSO_4$)	.0281	1.6413
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.2908	16.9856
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.1617	9.4448
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0012	.0701
Alumina (Al_2O_3)	.0096	.5607
Silica (SO_2)	.0051	.2979
Totals	2.4983	145.9257

Analysis by E. H. S. Bailey.

Centralia Gypsum Well.

There is a well two and one-half miles north of Centralia, in Nemaha county, that has attracted considerable attention on account of the amount of gypsum that the water contains. It is on the farm of A. Oberndorf, and is 125 feet deep. There is evidently quite a body of this mineral below the surface here.

[53] CENTRALIA WELL.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0315	Sodium oxid (Na_2O)	.0424
Potassium (K)	.0250	Potassium oxid (K_2O)	.0302
Ammonium (NH_4)	.0014	Ammonium (NH_4)	.0014
Calcium (Ca)	.4940	Calcium oxid (CaO)	.6921
Magnesium (Mg)	.1567	Magnesium oxid (MgO)	.2618
Aluminum (Al)	.0037	Aluminum oxid (Al_2O_3)	.0070
Iron (Fe)	.0028	Iron oxid (FeO)	.0036
Chlorin (Cl)	.0360	Chlorin (Cl)	.0360
Sulfuric acid ion (SO_4)	1.9506	Sulfuric anhydrid (SO_3)	1.6255
Nitrous acid ion (NO_2)	.0064	Nitrous anhydrid (N_2O_3)	.0045
Nitric acid ion (NO_3)	.0141	Nitric anhydrid (N_2O_5)	.0091
Phosphoric acid ion (PO_4)	.0627	Phosphoric anhydrid (P_2O_5)	.0468
Silicic acid ion (SiO_3)	.0300	Silicic anhydrid (SiO_2)	.0250
		Carbonic anhydrid (CO_2)	.6341
		Total	3.4196

Analysis by E. B. Knerr.

[54] Conway, McPherson County.

The water of a well at Conway has the following composition:

Grams per liter.

Sodium (Na)	.0386	Sodium oxid (Na_2O)	.0320
Potassium (K)	.0192	Potassium oxid (K_2O)	.0231
Lithium (Li)	trace	Lithium oxid (Li_2O)	trace
Calcium (Ca)	.5215	Calcium oxid (CaO)	.7308
Magnesium (Mg)	.0947	Magnesium oxid (MgO)	.1579
Iron (Fe)	trace	Iron oxid (FeO)	trace
Aluminum (Al)	.0551	Aluminum oxid (Al_2O_3)	.0104
Chlorin (Cl)	.0595	Chlorin (Cl)	.0595
Sulfuric acid ion (SO_4)	1.6546	Sulfuric anhydrid (SO_3)	1.3785
Boric acid ion (B_4O_7)	trace	Boric anhydrid (B_4O_6)	trace
Silicic acid ion (SiO_3)	.0181	Silicic anhydrid (SiO_2)	.0143
		Carbonic anhydrid (CO_2)	none

Analysis by G. H. Failyer and C. M. Breese.

53. Trans. Kan. Acad. Sci., vol. XII, p. 89.

54. Trans. Kan. Acad. Sci., vol. XI, p. 110.

Council Grove Magnesium Well.

This well is on the property of A.W. Simcock, four and one-half miles from the town of Council Grove and 100 yards from a running creek. It is twenty-five feet deep and ordinarily contains about eight feet of water. Council Grove is at the junction of the M. K. & T. and Mo. Pac. railroads. The water has been used locally with considerable success.

The partiai analysis is as follows:

COUNCIL GROVE (PARTIAL ANALYSIS).

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0061	Sodium oxid (Na_2O)	.0082
Calcium (Ca)	.4375	Calcium oxid (CaO)	.6690
Magnesium (Mg)	.2931	Magnesium oxid (MgO)	.4890
Iron (Fe)	.0157	Iron oxid (Fe_2O_3)	.0225
Chlorin (Cl)	trace	Chlorin (Cl)	trace
Sulfuric acid ion (SO_4)	2.3730	Sulfuric anhydrid (SO_3)	1.9775
Silicic acid ion (SiO_3)	.1868	Silicic anhydrid (SiO_2)	.1475
		Total	3.3137

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium sulfate (Na_2SO_4)	.0187	1.092
Sodium chlorid (NaCl)	trace	trace
Calcium sulfate ($CaSO_4$)	1.6245	94.887
Magnesium sulfate ($MgSO_4$)	1.4670	85.687
Ferric sulfate ($Fe_2(SO_4)_3$)	.0560	3.271
Silica (SiO_2)	.1475	8.615
Totals	3.3137	193.552

Analysis by E. H. S. Bailey and H. P. Cady.

Fagan, Graham County.

The water of a well at Fagan has the following composition:

Grams per liter.

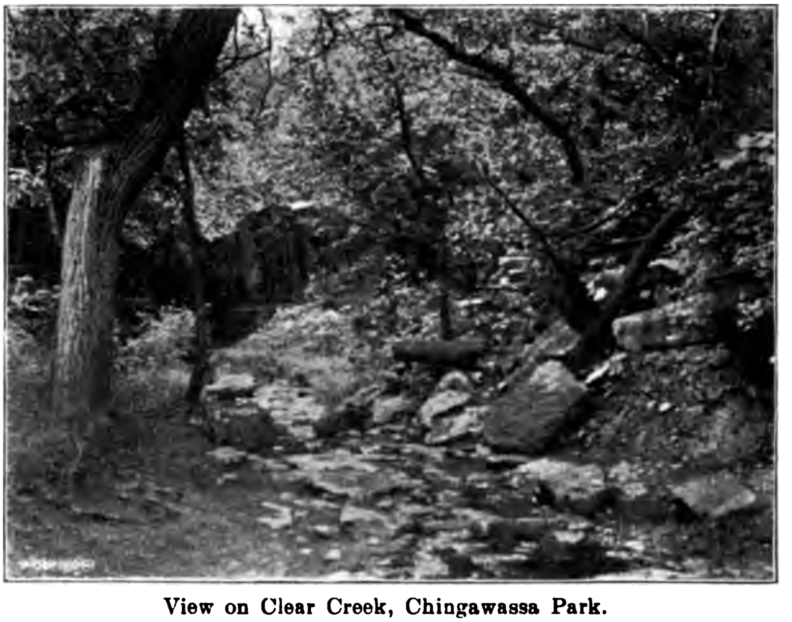
IONS.		RADICALS.	
Sodium (Na)	.0333	Sodium oxid (Na_2O)	.0449
Calcium (Ca)	.1537	Calcium oxid (CaO)	.2154
Magnesium (Mg)	.0190	Magnesium oxid (MgO)	.0317
Iron (Fe)	.0061	Iron oxid (FeO)	.0068
Chlorin (Cl)	.0512	Chlorin (Cl)	.0512
Sulfuric acid ion (SO_4)	.2691	Sulfuric anhydrid (SO_3)	.2241
Silicic acid ion (SiO_3)	.0321	Silicic anhydrid (SiO_2)	.0253
		Organic matter	.0080
		Carbonic anhydrid (CO_2)	.1668
		Water (H_2O)	.0343
		Oxygen equivalent	.0116
		Total	.7969

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0846	4.935
Calcium sulfate ($CaSO_4$)	.2751	16.073
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.2918	17.055
Magnesium sulfate ($MgSO_4$)	.0953	5.554
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0168	.983
Silica (SiO_2)	.0253	1.479
Organic matter	.0080	.466
Totals	.7969	46.545

Analysis by E. H. S. Bailey and E. C. Franklin.

Chingawassa Springs.



View on Clear Creek, Chingawassa Park.

Chingawassa Springs, Marion County.

These springs are situated in a beautiful park about six miles north of Marion. This park is near Antelope station, on the C. R. I. & P. railway, and within a radius of a quarter of a mile there are at least thirty springs, but most of them are fresh water. The water bubbles out of the bluffs in such quantities that a stream of no mean proportions takes its rise from this point. There are no less than four of these springs strongly impregnated with mineral matter.

IMPROVEMENTS.

In 1888 extensive improvements were made here, and a dummy line was built from Marion to the hotel at the springs. The plan of the promoters of the railroad also called for branches extending in several directions to the extensive limestone quarries in the vicinity. The citizens who had assisted in this enterprise found, however, that the developments that they had made were ahead of the times, and the park is at present used only as a picnic ground, and the improvements have been sold. The springs, however, are as numerous as ever, and the flow of water is not affected by local booms.

In this park there are grouped some of the finest springs in the state. The present owner is Doctor Rogers, of Marion. Samples of the various waters were taken by the author personally, and the result of the analysis of two of the most important springs is given below. From the north spring an inch and a half stream is constantly flowing, and from the south spring the flow is estimated at 1500 gallons per hour. On the bottom and sides of several of these springs may be seen a white deposit of sulfur, and in others the odor of hydrogen sulfid is quite apparent. A neat pavilion was formerly built over the north spring, and the water was conducted by pipes into the stream which runs in the vicinity.

[55] CHINGAWASSA SPRINGS (NORTH SPRING).

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0374	Sodium oxid (Na_2O)	.0505
Potassium (K)	.0039	Potassium oxid (K_2O)	.0048
Magnesium (Mg)	.0785	Calcium oxid (CaO)	.8422
Iron (Fe)	.0007	Magnesium oxid (MgO)	.1308
Chlorin (Cl)	.0280	Iron oxid (FeO)	.0009
Sulfuric acid ion (SO_4)	1.5244	Chlorin (Cl)	.0280
Silicic acid ion (SiO_3)	.0215	Sulfuric anhydrid (SO_3)	1.2704
		Silica (SiO_2)	.0162
		Carbonic anhydrid (CO_2)	.2320
		Water (H_2O)	.0463
		Oxygen equivalent	.0063
		Total	2.6158

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0461	2.6920
Sodium sulfate (Na_2SO_4)	.0538	3.1427
Sodium bicarbonate ($NaHCO_3$)	trace	trace
Sodium hydrosulfate (NaHS)	trace	trace
Calcium sulfate ($CaSO_4$)	1.6698	97.5369
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.4263	24.9043
Potassium sulfate (K_2SO_4)	.0083	.4907
Magnesium sulfate ($MgH_2(CO_3)_2$)	.3923	22.9183
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0030	.1752
Silica (SiO_2)	.0162	.9464
Totals	2.6158	152.8065

Carbon-dioxid gas, considerable.
Hydrogen-sulfid gas, a trace.
Temperature.................. 14° C. (57.2 F.)

Analysis by E. H. S. Bailey and E. C. Franklin.

South spring has similar composition:

Total solids.......................... 153.748 grains per gallon.
Temperature .... 14° C. (57.4° F.)
Flow, gallons per minute 25

55. Trans. Kan. Acad. Sci., vol. XII, p. 27.

[56] Madison Magnesium Well.

The water of a well about thirty feet deep, on the farm of Mr. A. Girard, of Madison, Kan., has the following composition:

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.5502	Sodium oxid (Na_2O)	.7414
Calcium (Ca)	.4081	Calcium oxid (CaO)	.5712
Magnesium (Mg)	.3845	Magnesium oxid (MgO)	.6403
Iron (Fe)	.0092	Iron and aluminum oxids (Fe_2O_3 and Al_2O_3)	.0118
Chlorin (Cl)	.0698	Chlorin (Cl)	.0698
Sulfuric acid ion (SO_4)	3.0535	Sulfuric anhydrid (SO_3)	2.5446
Silicic acid ion (SiO_3)	.0162	Silicic anhydrid (SiO_2)	.0128

Analysis by F. W. Bushong.

Neuchatel Well.

In the extreme southwest part of Nemaha county Neuchatel is situated. On the high land about the head waters of the Vermillion, and five miles due north of Onaga, on the property of William Swift, a well was bored in September, 1891. It was carried to a depth of 150 feet, and the water, being examined, was found to be strongly impregnated with salt and other mineral substances. This water yields 167 grains of mineral matter per gallon. This mineral matter consists of sodium chlorid, calcium carbonate, sodium sulfate, magnesium carbonate, silica, iron and aluminum oxids. From the composition, it is evident that the water has excellent cathartic properties.

Parsons Mineral Well.

About six miles east of Parsons, in Labette county, an important point on the M. K. & T. and St. L. & S. F. railroads, on the open prairie, is situated a well which was dug to supply stock with water. The mineral character of the water was noticed by the owner, Mr. Angell Mathewson, and an examination of the water was made. The well is thirty feet deep, and, as may be seen by the analysis which follows, the water is remarkable for containing large quantities of nitrates and an excess of magnesium salts. The presence of the nitrates was thought at

56. Trans. Kan. Acad. Sci., vol. XVII, p. 53.

first to indicate contamination, but from a knowledge of the situation of the well, and the fact that there seemed to be no opportunity for contamination, it is probable that the nitrates are associated with the sulfates normally in the soil and that there is no organic impurity in the water. No improvements have been made here.

PARSONS MINERAL WELL.[57]

Grams per liter.

IONS.		RADICALS.	
Potassium (K)	.0061	Potassium oxid (K_2O)	.0074
Sodium (Na)	.3304	Sodium oxid (Na_2O)	.4454
Calcium (Ca)	.4938	Calcium oxid (CaO)	.6914
Magnesium (Mg)	.8112	Magnesium oxid (MgO)	1.3528
Iron (Fe)	.0005	Ferrous oxid (FeO)	.0007
Chlorin (Cl)	.1404	Chlorin (Cl)	.1414
Sulfuric acid ion (SO_4)	4.4090	Sulfuric anhydrid (SO_3)	3.6742
Nitric acid ion (NO_3)	.0182	Nitric anhydrid (N_2O_5)	.0162
Silicic acid ion (SiO_3)	.0186	Silica (SiO_2)	.0146
Organic matter	trace	Carbonic anhydrid (CO_2)	.5199
		Water (H_2O)	.1080
		Oxygen equivalent	.0234
		Total	6.9486

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Potassium sulfate (K_2SO_4)	.1138	.8060
Sodium nitrate ($NaNO_3$)	.0255	1.4894
Sodium sulfate (Na_2SO_4)	.7434	43.4220
Sodium chlorid (NaCl)	.2330	12.6095
Sodium bicarbonate ($NaHCO_3$)	trace	trace
Calcium sulfate ($CaSO_4$)	.9080	53.0362
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.9496	55.4661
Magnesium sulfate ($MgSO_4$)	4.0584	237.0511
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0020	.1343
Silica (SiO_2)	.0146	.8527
Organic matter	trace	trace
Totals	6.9486	405.8673

Analysis by E. H. S. Bailey.

57. Trans. Kan. Acad. Sci., vol. XII, p. 27.

Stotler Well, Lyon County.[58]

The water of a well at Stotler has the following composition:

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0970	Sodium oxid (Na_2O)	.1308
Potassium (K)	.0554	Potassium oxid (K_2O)	.0668
Calcium (Ca)	.2133	Calcium oxid (CaO)	.2987
Magnesium (Mg)	.0560	Magnesium oxid (MgO)	.0934
Iron (Fe)	.0352	Iron oxid (FeO)	.0453
Chlorin (Cl)	.0169	Chlorin (Cl)	.0169
Sulfuric acid ion (SO_4)	.9476	Sulfuric anhydrid (SO_3)	.7897
Phosphoric acid ion (PO_4)	.0006	Phosphoric anhydrid (P_2O_5)	.0004
Silicic acid ion (SiO_3)	.0420	Silica (SiO_2)	.0332
		Carbonic anhydrid	not determined

Analysis by G. H. Failyer and J. T. Willard.

Sun Springs, Brown County.

These springs are located three miles southwest of the town of Morrill, Brown county, on the St. Joseph & Grand Island railway. This is a high, rolling country, and is well watered. These springs are in the valley of Mulberry creek, a stream that runs east and then north, and at last finds its way into the Nemaha.

IMPROVEMENTS.

This property was developed in 1898. The new hotel is just in the edge of the timber, a little to the north of the grove in which the springs are situated. A bath-house has also been erected, with baths for giving hot and cold baths, and a dam thrown across the valley makes a lake, which gives facilities for boating. There are a large number of springs within a radius of an eighth of a mile, and water is found in abundance wherever a small excavation is made in the ground. The soil seems to be peculiar in that it is very springy, and at a short distance below the surface is full of large nodules, consisting of clay and iron minerals.

The principal spring is No. 1, a few rods southwest of the hotel. This is improved by being built up and cemented to a point about three feet above the surface. It is eight feet in diameter and eight feet deep, and a stream nearly filling a

58. Trans. Kan. Acad. Sci., vol. X, p. 64.

Hotel at Sun Springs.

Lake near Sun Springs.

six-inch pipe constantly runs away from the spring. The flow is estimated at 5000 gallons per hour. In fact, this seems to be one of the largest springs in the state. The water boils up through the sand and broken shales at the bottom and is perfectly clear, and sometimes gives off a little hydrogen-sulfid gas.

Spring No. 2 is a short distance southwest of this. It is built up in the same way above the ground, and yields 600 gallons per hour. The flow of gas is more abundant from this spring than from No. 1.

Spring No. 3 is a short distance east of No. 2. It also has an abundant flow of water. The temperature is 14° C. (57.2° F.)

Spring No. 4 is east of the hotel. The water of this spring is used at the bath-house, which is near by.

There are other springs in the vicinity which have been only partially developed. The value of the improvements thus far made is from $2000 to $3000. The present proprietor is F. A. Gue, Hiawatha, R. F. D. No. 3. The analysis of the water of spring No. 1, which was made in 1898, is as follows:

Sun Springs, No. 1.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0663	Sodium oxid (Na_2O)	.0894
Calcium (Ca)	.5968	Calcium oxid (CaO)	.8356
Magnesium (Mg)	.0604	Magnesium oxid (MgO)	.1006
Iron (Fe)	.0017	Iron oxid (FeO)	.0022
Chlorin (Cl)	.0425	Chlorin (Cl)	.0425
Sulfuric acid ion (SO_4)	1.4088	Sulfuric anhydrid (SO_3)	1.1740
Silicic acid ion (SiO_3)	.0267	Silica (SiO_2)	.0211
		Carbonic anhydrid (CO_2)	.3190
		Water (H_2O)	.0651
		Oxygen equivalent	.0095
		Total	2.6400

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0701	4.0945
Sodium bicarbonate ($NaHCO_3$)	.0432	2.5233
Sodium sulfate (Na_2SO_4)	.0831	4.8538
Calcium sulfate ($CaSO_4$)	1.9169	111.9661
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.1329	7.7626
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.3672	21.4481
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0055	.3216
Silica (SiO_2)	.0211	1.2324
	2.6400	154.2024

Temperature .... 13° C. (55.4° F.)

Analysis by E. H. S. Bailey and D. F. McFarland.

Sun Springs, No. 2.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0198	Sodium oxid (Na_2O)	.0267
Calcium (Ca)	.7396	Calcium oxid (CaO)	1.0356
Magnesium (Mg)	.0003	Magnesium oxid (MgO)	.0007
Iron (Fe)	.0028	Iron oxid (FeO)	.0036
Chlorin (Cl)	.0248	Chlorin (Cl)	.0248
Sulfuric acid ion (SO_4)	1.3830	Sulfuric anhydrid (SO_3)	1.1520
Silicic acid ion (SiO_3)	.0228	Silica (SiO_2)	.0180
		Carbonic anhydrid (CO_2)	.3723
		Water (H_2O)	.0759
		Oxygen equivalent	.0055
		Total	2.7041

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chloride (NaCl)	.0408	2.3800
Sodium sulfate (Na_2SO_4)	.0114	.6650
Calcium sulfate ($CaSO_4$):	1.9419	113.2800
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.6814	39.7500
Magnesium sulfate ($MgSO_4$)	.0018	.1050
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0088	.5133
Silica (SiO_2)	.0180	1.0500
Totals	2.7041	157.7433

Temperature .... 11° C. (52° F.)

Analysis by E. B. Knerr.

Sun Springs, No. 3.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0369	Sodium oxid (Na_2O)	.0498
Potassium (K)	.0033	Potassium oxid (K_2O)	.0038
Calcium (Ca)	.6297	Calcium oxid (CaO)	.8816
Magnesium (Mg)	.0417	Magnesium oxid (MgO)	.0694
Iron (Fe)	.0018	Iron oxid (FeO)	.0023
Chlorin (Cl)	.0496	Chlorin (Cl)	.0496
Sulfuric acid ion (SO_4)	1.2902	Sulfuric anhydrid (SO_3)	1.0752
Silicic acid ion (SiO_3)	.0363	Silica (SiO_2)	.0288
		Carbonic anhydrid (CO_2)	.3711
		Water (H_2O)	.0759
		Oxygen equivalent	.0111
		Total	2.5964

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0770	4.4976
Sodium sulfate (Na_2SO_4)	.0205	1.1974
Potassium chlorid (KCl)	.0061	.3563
Calcium sulfate ($CaSO_4$)	1.5720	91.8205
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.6778	39.5903
Magnesium sulfate ($MgSO_4$)	.2084	12.1726
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0058	.3388
Silica (SiO_2)	.0288	1.6822
Totals	2.5964	151.6557

Analysis by E. B. Knerr.

Sun Springs, No. 4.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0601	Sodium oxid (Na_2O)	.0810
Potassium (K)	.0004	Potassium oxid (K_2O)	.0004
Calcium (Ca)	.5435	Calcium oxid (CaO)	.7610
Magnesium (Mg)	.0074	Magnesium oxid (MgO)	.0123
Iron (Fe)	.0025	Iron oxid (FeO)	.0032
Chlorin (Cl)	.0496	Chlorin (Cl)	.0496
Sulfuric acid ion (SO_4)	1.3885	Sulfuric anhydrid (SO_3)	1.1571
Silicic acid ion (SiO_3)	.0258	Silica (SiO_2)	.0204
		Carbonic anhydrid (CO_2)	.0079
		Water (H_2O)	.0016
		Oxygen equivalent	.0111
		Total	2.0834

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid ($NaCl$)	.0813	4.7430
Potassium chlorid (KCl)	.0007	0406
Sodium sulfate (Na_2SO_4)	.0871	5.0810
Calcium sulfate ($CaSO_4$)	1.8415	107.4500
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.0074	.4625
Magnesium sulfate ($MgSO_4$)	.0370	2.1585
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0080	.4667
Silica (SiO_2)	.0204	1.1900
Totals	2.0834	121.5923

Analysis by E. B. Knerr.

Sycamore Springs, Brown County.

In Brown county are situated several interesting groups of springs. At Springs post-office, five miles northwest of Morrill, six miles northeast of Sabetha, at the crossing of the St. J. & G. I. and the C. R. I. & P. railroads, and nine miles south of Salem, Neb., are located the Sycamore springs. They are in the valley of the Sycamore, a stream which runs north into the Nemaha river, and in the midst of some of the finest farming land in the state. The valley here is well wooded, many of the trees being large and evidently of great age.

IMPROVEMENTS.

The owner and proprietor is E. V. Kauffman, who has expended perhaps $2500 in rendering the springs more convenient of access and in improving the property. There is a frame hotel 24 x 60, three stories high, with accomodations for twenty-five guests. In this hotel is the post-office, dining-room, bath-rooms, with facilities for giving hot and cold baths, sweat baths, etc. There have also been erected two cottages, a refreshment stand, and livery barn, and the grounds have been cleared of underbrush, so that there is a very convenient space for those who prefer living in tents.

There are at least four important springs in this group: No. 1, near the hotel, discharges 1000 gallons per hour. No. 2, which discharges into a large tank, is delivered at the hotel. The flow is about 500 gallons per hour. No. 3 is a spring

Hotel at Sycamore Springs.

Spring and Park, Sycamore Springs.

under a part of the hotel building. The water has a temperature of 12° C. (53.5° F.) The flow is about 500 gallons per hour. No. 4 is a smaller spring, which evidently contains considerable iron. The water has a temperature of 12.5° C. (54.5° F.) The composition of the water is as follows:

Sycamore Springs, No. 1.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0572	Sodium oxid (Na_2O)	.0771
Potassium (K)	.0018	Potassium oxid (K_2O)	.0021
Calcium (Ca)	.6044	Calcium oxid (CaO)	.8460
Magnesium (Mg)	.0576	Magnesium oxid (MgO)	.0959
Iron (Fe)	.0014	Iron oxid (FeO)	.0018
Chlorin (Cl)	.0815	Chlorin (Cl)	.0815
Sulfuric acid ion (SO_4)	1.3665	Sulfuric anhydrid (SO_3)	1.1388
Silicic acid ion (SiO_3)	.0284	Silica (SiO_2)	.0224
		Carbonic anhydrid (CO_2)	.3005
		Water (H_2O)	.0613
		Oxygen equivalent	.0184
		Total	2.6090

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.1317	7.6926
Potassium chlorid (KCl)	.0034	.1986
Sodium sulfate (Na_2SO_4)	.0168	.9813
Calcium sulfate ($CaSO_4$)	1.5934	93.0705
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.5490	32.0671
Magnesium sulfate ($MgSO_4$)	.2879	16.8162
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0044	.2570
Silica (SiO_2)	.0224	1.3083
Totals	2.6090	152.3916

Temperature .... 12.5° C. (54.5° F.)

Analysis by E. B. Knerr.

Sycamore Springs, No. 2.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0492	Sodium oxid (Na_2O)	.0663
Potassium (K)	.0027	Potassium oxid (K_2O)	.0032
Calcium (Ca)	.6239	Calcium oxid (CaO)	.8734
Magnesium (Mg)	.0556	Magnesium oxid (MgO)	.0925
Iron (Fe)	.0017	Iron oxid (FeO)	.0021
Chlorin (Cl)	.0603	Chlorin (Cl)	.0603
Sulfuric acid ion (SO_4)	1.4550	Sulfuric anhydrid (SO_3)	1.2125
Silicic acid ion (SiO_3)	.0268	Silica (SiO_2)	.0212
		Carbonic anhydrid (CO_2)	.2656
		Water (H_2O)	.0542
		Oxygen equivalent	.0136
		Total	2.6377

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0967	5.6482
Potassium chlorid (KCl)	.0051	.2979
Sodium sulfate (Na_2SO_4)	.0343	2.0035
Calcium sulfate ($CaSO_4$)	1.7138	100.1031
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.4840	28.2704
Magnesium sulfate ($MgSO_4$)	.2773	16.1970
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0053	.3096
Silica (SiO_2)	.0212	1.2383
Totals	2.6377	154.0680

Temperature............... 12.5° C. (54.5° F.)

Analysis by E. B. Knerr.

Victoria Well, Ellis County.

On the Battell farm, near Victoria, is a shallow well, the water of which at first proved distasteful to stock, but to which, after a time, they became accustomed. A partial analysis of this water shows that it contains 120.89 grains of mineral matter per gallon, of which 14.37 grains is common salt. The other constituents are such as to indicate the presence of calcium sulfate, magnesium sulfate, and sodium sulfate, with small quantities of carbonates and nitrates.

Walton Well, Harvey County.

There is a well on the property of E. W. Slaymaker, which is sunk to a depth of fifty-five feet. There is such an abundant flow of water that continuous pumping produces little effect, only it has been noticed that the temperature of the water becomes lower. This well is on the top of a high hill, within a mile of the divide, the water to the west flowing southwest and to the northeast flowing northeast. As may be seen from the analysis below, this water contains considerable calcium sulfate.

[59] WALTON WELL.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0127	Sodium oxid (Na_2O)	.0141
Calcium (Ca)	.9786	Calcium oxid (CaO)	1.3700
Magnesium (Mg)	.0639	Magnesium oxid (MgO)	.1066
Iron and aluminum (Fe), (Al)	.0228	Iron and aluminum oxids (FeO and Al_2O)	.0294
Chlorin (Cl)	.0198	Chlorin (Cl)	.0198
Sulfuric acid ion (SO_4)	1.1407	Sulfuric anhydrid (SO_3)	.9506
Silicic acid ion (SiO_3)	.0937	Silica (SiO_2)	.0740

Analysis by E. H. S. Bailey and H. E. Davies.

White Rock, Jewell County.[60]

A spring five miles west of White Rock, Jewell county:

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.1319	Sodium oxid (Na_2O)	.1778
Potassium (K)	.1114	Potassium oxid (K_2O)	.1343
Lithium (Li)	.0014	Lithium oxid (Li_2O)	.0030
Calcium (Ca)	.5578	Calcium oxid (CaO)	.7809
Magnesium (Mg)	.4562	Magnesium oxid (MgO)	.7604
Iron (Fe)	.0092	Iron oxid (FeO)	.0119
Chlorin (Cl)	.0211	Chlorin (Cl)	.0211
Sulfuric acid ion (SO_4)	3.1713	Sulfuric anhydrid (SO_3)	2.6428
Phosphoric acid ion (PO_4)	.0003	Phosphoric anhydrid (P_2O_5)	.0002
Boric acid ion (B_4O_7)	trace	Boric anhydrid (B_4O_6)	trace
Silicic acid ion (SiO_3)	.0265	Silicic anhydrid (SiO_2)	.0209
		Carbonic anhydrid	not determined

Analysis by G. H. Failyer and J. T. Willard.

59. Trans. Kan. Acad. Sci., vol. XV, p. 87.

60. Trans. Kan. Acad. Sci., vol. X, p. 63.

Williamsburg, Franklin County.

The water of a well bored on the property of F. H. Welch, Williamsburg, has the following composition:

PARTIAL ANALYSIS.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.1565	Sodium oxid (Na_2O)	.2109
Calcium (Ca)	.9162	Calcium oxid (CaO)	1.2820
Magnesium (Mg)	.4850	Magnesium oxid (MgO)	.8082
Iron (Fe)	.0112	Iron oxid (FeO)	.0124
Chlorin (Cl)	.2022	Chlorin (Cl)	.2022
Sulfuric acid ion (SO_4)	2.9791	Sulfuric anhydrid (SO_3)	2.4826
Silicic acid ion (SiO_3)	.0851	Silicic anhydrid (SiO_2)	.0672

Analysis by E. H. S. Bailey and D. F. McFarland.

COMPARISON OF SIMILAR WATERS.

Waters of the sulfate group are especially abundant in Kansas, and are of great importance Some waters of this class in other localities are:

Crab Orchard Springs, Lincoln County, Kentucky.

Grains per gallon.

Analysis by R. Peter.

Sodium chlorid	17.728	Magnesium sulfate	205.280
Sodium sulfate	59.072	Silica	3.264
Potasium sulfate	9.912	Loss and moisture	34.582
Calcium carbonate	53.184	Total	401.454
Calcium sulfate	10.792		
Magnesium carbonate	7.640		

Bedford Springs, Pa.

Analysis by Doctor Church.

Sodium chlorid	9.000	Magnesium sulfate	80.000
Calcium carbonate	8.000	Iron carbonate	5.000
Calcium sulfate	15.000	Total	120.000
Calcium chlorid	3.000		

Carbon-dioxid gas.............. 74 cubic inches.
Temperature.................... 58° F.

Ofen, Hungary, Hunyadi-Janos.

Analysis by R. Fresenius.

Sodium chlorid	83.176	Magnesium sulfate	1077.635
Sodium sulfate	1148.463	Iron carbonate	.123
Potassium sulfate	7.763	Silica	.654
Calcium sulfate	77.212	Total	2437.741
Magnesium carbonate	42.715		

Free carbon-dioxid........... 217.44 cc. per liter.

Carabana, Spain.

Analysis by A. Proust.

Sodium chlorid	93.309	Magnesium chlorid	27.841
Sodium sulfate	5831.800	Magnesium sulfate	179.101
Sodium sulfid	2.910	Alumina	.029
Sodium phosphate	1.225	Total	6147.686
Calcium chlorid	11.471		

Kissingen, Bitter Wasser, Germany.

Analysis by Liebig.

Sodium chlorid	464.692	Calcium sulfate	78.643
Sodium sulfate	353.649	Magnesium carbonate	30.367
Potassium sulfate	11.582	Magnesium sulfate	300.414
Lithium chlorid	.730	Magnesium chlorid	229.761
Ammonium chlorid	.169	Magnesium bromid	6.652
Calcium carbonate	.858	Total	1477.521

Free carbon dioxid.......... 184.375 cc. per liter.

Carlsbad (Sprudel), Bohemia.

Analysis by Gottl.

Sodium chlorid	69.792	Magnesium carbonate	3.192
Sodium carbonate	72.496	Ferrous carbonate	.248
Sodium sulfate	159.680	Aluminum phosphate	1.720
Potassium sulfate	2.960	Silica	8.416
Calcium carbonate	16.020	Total	334.524

Carbon-dioxid gas........... 62.40 cubic inches.
Nitrogen.................... .24 "

Pullna, Bohemia.

Analysis by Struve.

Sodium sulfate	990.400	Magnesium sulfate	744.688
Potassium sulfate	38.400	Magnesium carbonate	51.248
Calcium sulfate	20.800	Magnesium chlorid	157.328
Calcium carbonate	6.160	Silica	1.408
Calcium phosphate	.024	Total	2010.456

A Comparison of the Most Important Constituents of the Waters of the *Sulfate* Group.

Grains per gallon.

NAME.	Total solids.	Sodium chlorid.	Sodium sulfate.	Calcium sulfate.	Calcium bicarbonate.	Magnesium sulfate.
Abilena	4244	34	4015	47	61	87
Capioma	246	31	37	86	24	64
Carbondale	145	76	37	1	16	....
Council Grove	193	trace	1	94	....	85
Fagan	46	4	....	16	17	5
Chingawassa	152	2	3	97	24	22
Parsons	405	13	43	58	55	237
Sun No. 1	154	4	4	111	7	....
Sycamore No. 1	152	7	1	93	32	16
Crab Orchard, Ky	401	17	59	10	53	205
Bedford, Pa	124	9	....	15	8	80
Hunyado Janos	2437	83	1148	77	....	1077
Carabaña, Spain	6147	93	5831	....	....	197
Kissingen, Germany	1477	464	353	78	1	300
Carlsbad, Bohemia	334	69	159	....	16	....
Püllna, Austria	2010	....	990	20	6	744

This comparison shows that while these waters usually contain sodium chlorid, the percentage of this salt is small compared with the total mineral matter. On the other hand, the amount of sulfates is large; in some cases, very large. Carbonates of calcium and magnesium are also present in considerable quantity, and sometimes enough sodium carbonate to give the water a strong alkaline reaction. In addition to magnesium sulfate, magnesium carbonate and chlorid are also frequently mentioned.

Some very interesting comparisons may be brought out, showing the value of the Kansas waters. There is a remarkable similarity in composition between the Abilena and certain foreign waters, notably the Hunjadi-Janos, Carabana, etc. The water of the Parsons well, a water that has hardly acquired even a local reputation for its therapeutic qualities, is very similar to that of Crab Orchard, Ky. The latter is used in making the celebrated "Crab Orchard Salts," which are so extensively

used in Kentucky and neighboring states as a cathartic. The analysis of the Crab Orchard salts, as given by Dr. Robert Peter, is as follows :

100 parts contain—		
Magnesium sulfate	63.19	parts.
Sodium sulfate	4.20	"
Potassium sulfate	1.80	"
Calcium sulfate	2.54	"
Sodium chlorid	4.77	"
Lime, magnesia, iron, and silica (carbonates)	.89	"
Bromin	trace	
Water of crystallization and loss	22.61	"
Total	100.00	parts.

Other waters, like Carbondale and Capioma, contain similar constituents, but the waters are more dilute.

The second class of waters, those in which calcium sulfate and magnesium sulfate are prominent constituents, are similar to such waters as Bedford Springs, Pennsylvania.

CHAPTER XII.

The Chlor-Sulfate Group.

These are waters which retain many of the constituents of the chlorid group, yet contain sulfates in considerable abundance. They would have the laxative character of the strong sulfate waters mentioned in the previous group, but this would be somewhat modified by the presence of chlorids and often carbonates.

This group is represented by the following waters:

Carbondale, Osage county, Merrill spring.
Great Bend, Barton county.
Great Spirit Springs, Mitchell county.
Leavenworth, Mountain Dew.
Lincoln Springs, Lincoln county.
Little River, Rice county.
Marion, Marion county, upper vein.
Overbrook, Osage county.
Topeka, Shawnee county, Boon well.
Topeka, Shawnee county, Phillips's well.

Merrill Mineral Spring.

Southeast of the Carbondale well, on the opposite side of the street in a little depression, is situated the Merrill mineral spring. The flow of this is said to be 600 gallons per hour, and the water is supposed to come from a fissure in the rock several hundred feet in depth. It is seventeen feet down to this fissure, and a tile two feet in diameter is cemented to this. By this means the water is brought to within eight feet of the surface, and from this point the water is raised by means of a pump and windmill and stored in a large cistern.

There was a large bath and pavilion, for the convenience of visitors, but since their destruction by fire the only improve-

ments are the sanitarium and hotel, a few rods to the northeast of the spring, in a luxuriant grove. This sanitarium is owned by Dr. H. H. Swallow, and here a limited number of patients, especially those suffering from nervous diseases, are treated. One peculiarity of the Merrill spring is that it contains a considerable quantity of ammonia. In 1888 this fact gave rise to a special investigation by the city of Topeka. It was found to contain 0.246 parts in 100,000 of free ammonia, and 0.0018 parts in 100,000 of albuminoid ammonia. From a personal inspection of the locality, it was evident to the author that this large amount of free ammonia did not indicate any contamination by sewage or otherwise, but that the ammonia must be a natural constituent of the water of this locality. This same fact has been observed in reference to numerous other waters in the Mississippi valley.

MERRILL SPRING (NEAR CARBONDALE).

IONS.	Grams per liter.
Sodium (Na)	1.6585
Calcium (Ca)	.0081
Magnesium (Mg)	.0088
Iron (Fe)	.0006
Aluminum (Al)	.0018
Chlorin (Cl)	1.6520
Sulfuric acid ion (SO_4)	1.2139
Silic acid ion (SiO_3)	.0018

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon
Sodium chlorid (NaCl)	2.7400	132.44
Sodium sulfate (Na_2SO_4)	1.7590	102.60
Calcium sulfate ($CaSO_4$)	.0088	5.16
Calcium carbonate ($CaCO_3$)	.0137	8.00
Magnesium sulfate ($MgSO_4$)	.0333	19.45
Magnesium carbonate ($MgCO_3$)	.0077	4.52
Iron carbonate ($FeCO_3$)	.0012	.70
Alumina (Al_2O_3)	.0034	2.00
Silica (SiO_2)	.0025	1.50
Organic and volatile	.0015	.89
Traces of potassium, lithium, ammonium.		
Total solids	4.5711	277.26

Analysis by Dr. Albert Merrill, St. Louis.

Great Bend, Barton County, Mineral Well.

A well 1100 feet in depth was bored by a gas-prospecting company about 1888. Water was struck at a depth of 350 feet, and at 1000 feet salt water was found to be abundant. The water rises in a four-inch pipe, and runs over the top at a height of seventy-five feet from the ground. An analysis of the water gave the following result:

GREAT BEND WELL.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	22.4535	Sodium oxid (Na_2O)	30.2609
Calcium (Ca)	.6617	Calcium oxid (CaO)	.9260
Magnesium (Mg)	.6925	Magnesium oxid (MgO)	1.1542
Aluminum (Al)	trace	Aluminum oxid (Al_2O_3)	trace
Chlorin (Cl)	33.0587	Chlorin (Cl)	33.0587
Sulfuric acid ion (SO_4)	4.7876	Sulfuric anhydrid (SO_3)	3.9896
Silicic acid ion (SiO_3)	.0506	Silicic anhydrid (SiO_2)	.0400
		Carbonic anhydrid (CO_2)	1.4620
		Water (H_2O)	.2990
		Oxygen equivalent	7.4711
		Total	63.7193

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	54.5380	3185.565
Sodium sulfate (Na_2SO_4)	3.0001	175.236
Calcium sulfate ($CaSO_4$)	2.2489	131.358
Magnesium sulfate ($MgSO_4$)	1.4659	85.623
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	2.4264	141.726
Silica (SiO_2)	.0400	2.336
Alumina (Al_2O_3)	trace	trace
Totals	63.7193	3721.844

Analysis by E. H. S. Bailey.

Great Spirit Spring, Waconda, Mitchell County.

This is without doubt the most interesting and the best-known mineral spring in Kansas. It is situated at Waconda station, on the Central Branch of the Missouri Pacific railroad. Tradition tells us that from the earliest times the Indians who hunted over these plains held this spring in devout reverence. We quote from the description by Professor Patrick:[61]

61. Trans. Kans. Acad. Sci., vol. VII, pp. 22-26.

"The spring, distant from Cawker City about two and one-half miles, in a southeasterly direction, is just within the lower bottom of the Solomon river, being perhaps 300 feet from the first terrace, and about sixty rods from the present bed of the river. It flows, not after the manner of most springs, from some hidden nook or cavern, but from the summit of a nearly symmetrical mound, shaped like a low-statured sugar-loaf, or, to be more mathematical, like a truncated cone. This mound is forty-two feet high (see frontispiece), nearly as level on the top as a floor, and in the center of this small table-land is found the spring itself, which is quite as remarkable as are its surroundings. Instead of a gurgling rivulet, trickling away among the rocks, the visitor sees before him a smooth, almost motionless body of water, more than fifty feet across, and filling its basin to overflowing; or, if not to actual overflowing, so near it that its surface appears to be upon a level with the top of the mound, and in imminent danger of flowing over at any and all points. The only reason why such overflow does not occur is, that the rock forming the mound is very porous, and affords innumerable minute outlets, just equaling in combined capacity the subterranean inlet.

"The dimensions of the mound and basin are as follows, from actual measurements: Height of mound, 42 feet; diameter at base, 300 feet; diameter at top, 150 feet. The basin, shaped like a funnel, or better, like an inverted cone, is 35 feet deep at the center; its diameter at top, from 'water's edge to water's edge,' is, north to south, 52 feet 4 inches; east to west, 56 feet 8 inches. These figures show the surface of the pool to be very nearly circular. The limestone stratum enclosing it like a ring, of almost uniform width, makes a fine driveway for carriages, which find an easy ascent at one especially favorable point.

"The reverence with which the Indians have always regarded the 'Waconda' spring is worthy of notice, as exhibiting in a marked degreee some mental traits of a race destined soon to pass away. Upon this subject my knowledge is all at second-hand, but I am fortunate in having the following statement from one of the earliest settlers of Mitchell county, now a resi-

Hotel at Waconda, Great Spirit Springs.

Southern Exposure of Great Spirit Spring Mound.

dent of Cawker City, a man whose character vouches for the truth of his words. In response to a request from me, he writes: 'In answer will say, that through Indian interpreters I have the statement from various tribes visiting our spring, that Waconda, the daughter of a great Indian chief, at one time became infatuated with the son of another chief. The two tribes met at the spring, and, being hostile to each other, the intimacy was strongly opposed by the parents, and a conflict ensued. The lover of Waconda, being wounded and weak from loss of blood, fell or was hurled into the pool, whereupon Waconda plunged in after him, and both were drowned. Ever since the spring has been called "Waconda," or the "Great Spirit" spring, and the Indians believe that the spirit of Waconda still dwells in the mound, and sometimes becomes offended at bad Indians, and throws up vast volumes of water, drowning them. The Pottawatomies, who have often been through here in their hunts since this country was settled, could never be prevailed upon to pass the spring without stopping to have a regular powwow and dip their arrows into its waters. On one occasion we invited 300 Indians, who were on a buffalo hunt, and were camped near the spring, to come up to Cawker City and give us a war-dance. They accepted, but on no condition would they come until they had been to the spring and daubed their faces and ponies with the gray mud from its banks, and when they came their appearance in the light of the bonfires, built for the occasion, was frightful in the extreme.'

"From the same gentleman, as well as from others, I learn that many relics have been fished from the pool, including bows and arrows, a bent rifle or two, arrow-heads, colored stones, medals and beads (one medal bearing the stamp, 'The Fur Company of 1844,' and the figures of a white man and an Indian making friends over a pipe of peace), articles thrown in probably to propitiate the Great Spirit."

This spring reminds one of the High Rock spring of Saratoga, N. Y., which was frequented by the Indians as early as the fourteenth century. It was called by them the "Medicine Spring of the Great Spirit." Professor Chandler, in writing

of the High Rock spring, says:[62] "The spring rises in a little mound of stone three or four feet high, which appears like a miniature volcano, except that sparkling water instead of melted lava flows from its little crater. When Sir William Johnson visited the spring, in 1767, the water did not overflow the mound, but came to within a few inches of the summit, some other hidden outlet permitting it to escape." This small mound was afterwards undermined in order to repair the spring, and under it were found four logs, two of which rested on the other two at right angles, forming a curb. These rested on the black soil of a previous swamp. It was evident that the rock was built up by a deposit from the water.

IMPROVEMENTS.

The property has been in litigation in various actions almost continuously for twelve or fifteen years, and on this account comparatively little was done towards its development for some time. There is, however, a hotel with accommodations for twenty-five guests. Hot and cold baths are provided. The present proprietor is G. W. Cooper. The grounds in the vicinity of the sanitarium have been graded, and 600 shade-trees are growing. Not less than $10,000 has been expended in fitting up the property. About 300 cases of the water were shipped last year, besides large quantities sent away in jugs and kegs.

From an examination of the locality made by the author,[63] it is shown that "there is but little indication of organic matter in the water of the large spring, though there is a slimy white deposit adhering to the bottom and sides, but the water is colorless, clear, and transparent. The excess of water, instead of overflowing the bank, escapes by numerous small fissures, from ten to twenty feet down on the sides, especially on the side away from the bluff. In these lateral springs there is an abundance of green algæ and a whitish scum, which seems to be detached from the bottom and to float to the surface. This has a slimy, granular feeling, suggesting in a very marked manner hydrated silica.

62. American Chemist, vol. II.

63. Kans. Univ. Quart., vol. I, p. 85.

"The mound is situated within 200 feet of a limestone bluff, which rises perhaps twenty feet above the level of the spring. The natural inference would be that the harder material of the mound protected it from erosion, which carried away the rock in the valley of the Solomon on the south, and the rock between the spring and the bluff.

"Is it not possible, however, that the mound has been really made by the successive deposits from the spring? Although the mound is plainly stratified, this need not interfere with the theory, for the water may have been intermittent in its flow. The rock is very porous, and on being ground to a thin section is shown to be concretionary in structure.

"An analysis of the water of the spring showed that it contained over 1120 grains of mineral matter per gallon, of which 775 grains were sodium chlorid and 206 grains sodium sulfate, with 66 grains of magnesium sulfate, 41 grains of magnesium carbonate, and 31 grains of calcium carbonate. An analysis by the author shows that there are 0.874 grains of silica.

"Samples of the rock composing the mound and of the adjoining bluff were secured, and comparative analyses made, with the following result:

	Country rock.	Great Spirit mound.
Silica and insoluble residue	2.14	4.10
Oxides of iron and alumina	3.22	2.66[64]
Sulfuric anhydrid	.00	0.34
Carbon dioxid	40.90	39.10
Calcium oxid	51.90	41.28
Magnesium oxid	.63	1.15
Water and organic matter undetermined	1.21	3.37[65]
	100.00	100.00
Specific gravity	2.52	2.79

"The rocks are entirely different in appearance and structure, that of the mound being twice as hard as that of the bluff. The former contains much organic matter, as is shown by blackening when it is heated in a tube and by its giving off a characteristic odor. The iron is practically of the ferrous variety, probably combined with carbonic acid, and the rock con-

64. Mostly FeO., and so calculated.

65. With alkalies.

tains traces of chlorids. The particular sample taken was at some distance from the spring, and had been thoroughly exposed to the weather.

"The rock of the mound is of just such a character as might have been built up by deposition from the water, as it contains the least soluble constituents of the water. The process of solidification would have been assisted by the silica in the water, forming insoluble cementing silicates, as noticed by Professor Patrick. The analysis given above shows that there is abundant silica in the water for this purpose.

"Mention has been made of the organic growth in the adjacent springs. The mixed scum, on being heated, changes from a dull green to a vivid grass green, and if ignited it swells up and emits an ill-smelling vapor, which is evidently nitrogenous in its character. A grayish white ash is left, which contains much carbonate of lime. This is evidently freshly deposited, as it is entangled in the algæ in granular lumps.

"A specimen of the white scum noticed above only slightly mixed with the green algæ, was analyzed. The acid solution of the ash contains 1.26 per cent. of soluble silica. This was of course combined silica, probably calcium silicate, which becomes the cementing material in the rock. In another sample of ash, after removing all the substances soluble in hot water, the residue was found to contain 76.46 per cent. of silica."

GREAT SPIRIT SPRING (WACONDA NO. 1).[66]

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	6.3811	Sodium oxid (Na_2O)	8.6008
Calcium (Ca)	.2152	Calcium oxid (CaO)	.3014
Magnesium (Mg)	.4271	Magnesium oxid (MgO)	.7124
Chlorin (Cl)	8.0567	Chlorin (Cl)	8.0567
Bromin (Br)	.0031	Bromin (Br)	.0031
Sulfuric acid ion (SO_4)	3.3054	Sulfuric anhydrid (SO_3)	2.7591
Nitrous acid ion (NO_4)	trace	Nitrous anhydrid (N_2O_3)	trace
Silicic acid ion (SiO_3)	trace	Silica (SiO_2)	trace
		Carbonic anhydrid (CO_2)	1.2016
		Water (H_2O)	.2474
		Oxygen equivalent	1.8210
		Total	20.0611

66. Trans. Kans. Acad. Sci., vol. VII, pp. 22-26.

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid ($NaCl$)	13.2913	780.202
Sodium bromid ($NaBr$)	.0040	.234
Sodium sulfate (Na_2SO_4)	3.5385	206.572
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.8720	50.933
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	1.2226	71.412
Magnesium sulfate ($MgSO_4$)	1.1327	66.161
Silica (SiO_2)	trace	trace
Nitrous acid (NO_4)	minute trace	minute trace
Organic matter	none	none
Totals	20.0611	1168.842

Analysis by Prof. G. E. Patrick.

GREAT SPIRIT SPRING (WACONDA NO. 1.)

(New analysis, 1901.)

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	6.3075	Sodium oxid (Na_2O)	8.5007
Calcium (Ca)	.1443	Calcium oxid (CaO)	.2023
Magnesium (Mg)	.3940	Magnesium oxid (MgO)	.6573
Iron (Fe)	.0060	Iron oxid (FeO)	.0078
Chlorin (Cl)	7.7703	Chlorin (Cl)	7.7703
Sulfuric acid ion (SO_4)	3.3475	Sulfuric anhydrid (SO_3)	2.7896
Silicic acid ion (SiO_3)	.0218	Silicic anhydrid (SiO_2)	.0172
		Carbonic anhydrid (CO_2)	1.1082
		Water (H_2O)	.2264
		Oxygen equivalent	1.7538
		Total	19.5260

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid ($NaCl$)	12.8238	749.0381
Sodium sulfate (Na_2SO_4)	3.7949	221.6600
Sodium bicarbonate ($NaHCO_3$)	.0987	1.0046
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.5852	34.1815
Magnesium sulfate ($MgSO_4$)	.9786	57.1600
Magnesium bicarbonate (MgH_2CO_3),	1.2085	70.5884
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0191	1.1156
Silica (SiO_2)	.0172	5.7650
Totals	19.5260	1140.5132

Analysis by E. H. S. Bailey and D. F. McFarland.

Great Spirit Spring No. 2.

It may be of interest in this connection to note the character of another spring in the immediate vicinity.[67] This spring, "Waconda No. 2," is about half a mile southeast of the Great Spirit spring. It is surrounded on three sides by the bend of the river, and though water cannot be seen to come up through the rock, there is probably a rock deposit beneath the alluvium of the valley and no doubt the water comes up through the crevices of this rock. This spring has the following composition :

[68]GREAT SPIRIT SPRING (WACONDA NO. 2).

Grams per liter.

IONS.		RADICALS.	
Potassium (K)	.1759	Potassium oxid (K_2O)	.2120
Sodium (Na)	5.5890	Sodium oxid (Na_2O)	7.5330
Calcium (Ca),	.2761	Calcium oxid (CaO)	.3866
Magnesium (Mg)	.3689	Magnesium oxid (MgO)	.6148
Aluminum (Al)	.0089	Aluminum oxid (Al_2O_3)	.0166
Chlorin (Cl)	7.4000	Chlorin (Cl)	7.4000
Sulfuric acid ion (SO_4)	3.2362	Sulfuric anhydrid (SO_3)	2.6950
Boric acid ion (B_4O_7)	trace	Boric anhydrid (B_4O_6)	trace
Silicic acid ion (SiO_3)	.0148	Silica (SiO_2)	.0153
		Carbonic anhydrid (CO_2)	.6886
		Water (H_2O)	.1406
		Oxygen equivalent	1.6720
		Total	18.0305

Hypothetically combined as follows :

	Grams per liter.	Grains per gallon.
Potassium sulfate (K_2SO_4)	.3924	22.9201
Sodium chlorid (NaCl)	12.2084	713.0926
Sodium sulfate (Na_2SO_4)	2.4112	140.8382
Sodium biborate ($Na_2B_4O_7$)	trace	trace
Calcium bicarbonate ($CaH_2(CO_3)_2$)	1.1185	65.3315
Magnesium sulfate ($MgSO_4$	1.7349	101.8083
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.1331	7.7749
Aluminum oxid (Al_2O_3)	.0166	.9696
Silica (SiO_2)	.0153	.8936
Totals	18.0305	1053.6289

Analysis by E. H. S. Bailey and M. E. Rice.

67. Trans. Kans. Acad. Sci., vol. XIV, p. 49.

68. Kans. Univ. Quart.

Comparing this water with that of the Great Spirit spring as stated above, and supposing the two waters to be combined as has previously been noted, the comparison would be as follows:

	Grains per gallon. Waconda No. 2.	Great Spirit spring.
Potassium sulfate (K_2SO_4)	22.860	....
Sodium sulfate (Na_2SO_4)	143.065	206.357
Sodium chlorid (NaCl)	711.147	775.703
Sodium bicarbonate ($Na_2B_4O_7$)	trace	....
Calcium bicarbonate ($CaH_2(CO_3)_2$)	....	....
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	....	....
Magnesium sulfate ($MgSO_4$)	99.093	66.050
Iron and alumina (Al_2O_3, Fe_2O_3)	.969	....
Silica (SiO_2)	.0892	.0874

It will be readily seen that these waters are much alike, and that the important constituents are in about the same proportion. As would be expected, the spring in the valley, subject to erosion by high waters, would not show the same tendency to build up a mound as one situated on high ground.

There is still another spring a short distance south of this just described, which is immediately in the bed of the river, and covered by the stream during high water.

Leavenworth, Mountain Dew Spring.

(Home-Riverside Coal-mining Company.)

The water of this spring or well is obtained at a depth of sixty feet in the No. 1 plant of the Home mine. The water is discharged by the continuous operation of a Deane pump, with three-fourths-inch discharge.

IONS	Grams per liter.
Sodium (Na)	.1450
Calcium (Ca)	.2115
Magnesium (Mg)	.1096
Iron (Fe)	.0014
Chlorin (Cl)	.1321
Sulfuric acid ion (SO_4)	.8331
Silicic acid ion (SiO_3)	.0282

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.2180	12.73
Sodium sulfate (Na_2SO_4)	.1820	10.62
Calcium sulfate ($CaSO_4$)	.3839	22.40
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.3890	22.70
Magnesium sulfate ($MgSO_4$)	.5488	32.12
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0046	.27
Silica (SiO_2)	.0223	1.30
Totals	1.7486	102.14

Analysis by O. F. Stafford.

Lincoln County.

There are three springs located eleven miles northwest of Lincoln Center. This locality is something over twenty miles southeast of the Great Spirit springs, at Waconda, in Mitchell county. The exact location is on the southwest quarter of section 1, township 10, range 8. No improvements have been made on the property. The analysis made in 1887 is as follows:

LINCOLN SPRINGS NO. 1.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	6.9939	Sodium oxid (Na_2O)	9.4258
Potassium (K)	.0874	Potassium oxid (K_2O)	.1054
Lithium (Li)	.0002	Lithium oxid (Li_2O)	.0004
Calcium (Ca)	.2858	Calcium oxid (CaO)	.4002
Magnesium (Mg)	.3990	Magnesium oxid (MgO)	.6651
Iron (Fe)	.0225	Iron oxid (FeO)	.0290
Aluminum (Al)	.0002	Aluminum oxid (Al_2O_3)	.0005
Chlorin (Cl)	9.2465	Chlorin (Cl)	9.2465
Sulfuric acid ion (SO_4)	3.1092	Sulfuric anhydrid (SO_3)	2.5910
Boric acid ion (B_4O_7)	.0049	Boric anhydrid (B_4O_6)	.0044
Nitric acid ion (NO_3)	trace	Nitric anhydrid (N_2O_3)	trace
Silicic acid ion (SiO_3)	.0683	Silicic anhydrid (SiO_2)	.0540
		Organic matter	.1000
		Carbonic anhydrid (CO_2)	1.2502
		Water (H_2O)	.2557
		Oxygen equivalent	2.0897
		Total	22.0385

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	15.2496	890.729
Sodium bicarbonate $NaHCO_3$)	.0840	4.906
Sodium sulfate (Na_2SO_4)	2.9611	172.968
Sodium biborate ($Na_2B_4O_7$)	.0070	.408
Sodium nitrate ($NaNO_3$)	trace	trace
Potassium sulfate (K_2SO_4)	.1950	11.389
Lithium chlorid (LiCl)	.0013	.075
Calcium sulfate ($CaSO_4$)	.9715	56.746
Magnesium sulfate ($CaSO_4$)	.3930	22.955
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	1.9495	113.871
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0720	4.205
Alumina (Al_2O_3)	.0005	.029
Silica (SiO_2)	.0540	3.145
Organic matter	.1000	5.841
Totals	22.0385	1287.267

Analysis by E. H. S. Bailey and E. C. Franklin.

LINCOLN SPRINGS NO. 2.

Grams per liter.

IONS.		RADICALS.	
Potassium (K)	.0516	Potassium oxid (K_2O)	.0622
Sodium (Na)	7.5662	Sodium oxid (Na_2O)	10.1979
Lithium (Li)	.0011	Lithium oxid (Li_2O)	.0262
Calcium (Ca)	.3091	Calcium oxid (CaO)	.4329
Magnesium (Mg)	.4731	Magnesium oxid (MgO)	.7886
Iron (Fe)	.0008	Iron oxid (FeO)	.0020
Aluminum (Al)	.0021	Aluminum oxid (Al_2O_3)	.0047
Chlorin (Cl)	10.5251	Chlorin (Cl)	10.5251
Sulfuric acid ion (SO_4)	3.5268	Sulfuric anhydrid (SO_3)	3.0215
Boric acid ion (B_4O_7)	.0012	Boric anhydrid (B_4O_6)	.0045
Nitric acid ion (NO_3)	trace	Nitric anhydrid (N_2O_5)	trace
Silicic acid ion (SiO_3)	.0145	Silica (SiO_2)	.0115
		Carbonic anhydrid (CO_2)	.6196
		Water (H_2O)	.1260
		Oxygen equivalent	2.3785
		Total	23.4442

Specific gravity 1.0181

Combined as follows:

	Grams per liter.	Grains per gallon.
Sodium bicarbonate ($NaHCO_3$)	.0840	4.9064
Sodium biborate ($Na_2B_4O_7$)	.0065	.3796
Sodium nitrate ($NaNO_3$)	trace	trace
Sodium sulfate (Na_2SO_4)	2.2953	134.0689
Sodium chlorid ($NaCl$)	17.2617	1008.2569
Potassium sulfate (K_2SO_4)	.1152	6.7288
Lithium chlorid ($LiCl$)	.0740	4.3213
Calcium sulfate ($CaSO_4$)	1.0511	61.3947
Magnesium sulfate ($MgSO_4$)	1.5854	92.6032
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.9497	55.4719
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0051	.2978
Alumina (Al_2O_3)	.0047	.2745
Silica (SiO_2)	.0115	.6717
Totals	23.4442	1369.3757

Analysis by E. H. S. Bailey and E. C. Franklin.

LINCOLN SPRINGS NO. 3.

Grams per liter.

IONS.		RADICALS.	
Potassium (K)	.0070	Potassium oxid (K_2O)	.0085
Sodium (Na)	8.4127	Sodium oxid (Na_2O)	11.0389
Lithium (Li)	.2122	Lithium oxid (Li_2O)	.0261
Calcium (Ca)	.2456	Calcium oxid (CaO)	.3442
Magnesium (Mg)	.2867	Magnesium oxid (MgO)	.4779
Iron (Fe)	.0011	Iron oxid (FeO)	.0030
Aluminum (Al)	.0018	Aluminum oxid (Al_2O_3)	.0034
Chlorin (Cl)	10.6856	Chlorin (Cl)	10.6856
Sulfuric acid ion (SO_4)	3.7291	Sulfuric anhydrid (SO_3)	3.1076
Boric acid ion (B_4O_7)	.0038	Boric anhydrid (B_4O_6)	.0023
Nitric acid ion (NO_3)	trace	Nitric anhydrid (N_2O_5)	trace
Silicic acid ion (SiO_3)	.3447	Silica (SiO_2)	.2723
		Carbonic anhydrid (CO_2)	.6425
		Water (H_2O)	.1420
		Oxygen equivalent	2.4148
		Total	24.3395

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Potassium sulfate (K_2SO_4)	.0158	.9228
Sodium bicarbonate ($NaHCO_3$)	.0588	3.4345
Sodium biborate ($Na_2B_4O_7$)	.0083	.4848
Sodium nitrate ($NaNO_3$)	trace	trace
Sodium sulfate (Na_2SO_4)	3.9194	228.9321
Sodium chlorid (NaCl)	17.5265	1023.7228
Lithium chlorid (LiCl)	.0740	4.3223
Calcium sulfate ($CaSO_4$)	.8359	48.8250
Magnesium sulfate ($MgSO_4$)	.6007	35.0869
Magnesium bicarbonate ($MgH_2(CO_3)_2$),	1.0171	59.4089
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0073	.4264
Alumina (Al_2O_3)	.0034	.1986
Silica (SiO_2)	.2723	15.9050
Totals	24.3395	1421.6701

Analysis by E. H. S. Bailey and E. C. Franklin.

Little River.

On the farm of A. G. Wolf, near Little River, Rice county, a well was dug to the depth of seventy-five feet and then drilled into rock, in and below which was found an abundant supply of water. This is interesting as showing the saline character of the water at this depth. At greater depths, in nearly all sections in this locality, salt beds have been disclosed by the prospector's drill, and at Lyons and Sterling notably the salt is mined or the salt water is pumped from the well and used for the manufacture of salt. The qualitative analysis of the water of the Wolf well shows that it contains 547 grains of mineral matter per gallon, about half of which is sodium chlorid, the remainder calcium sulfate, calcium carbonate, magnesium carbonate, sodium carbonate, with traces of other substances. The water is alkaline to test paper. So far it has only been used locally for skin diseases, though it is claimed to be valuable in diseases of the alimentary canal. Although this water is in reality a brine, yet cattle after a short time become accustomed to its use and seem to thrive upon it.

Marion Well (Upper Vein).[69]

For description, chapter X.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.4499	Sodium oxid (Na_2O)	.6064
Calcium (Ca)	.3815	Calcium oxid (CaO)	.5341
Magnesium (Mg)	.2239	Magnesium oxid (MgO)	.3733
Iron (Fe)	.0039	Iron oxid (FeO)	.0050
Chlorin (Cl)	.5780	Chlorin (Cl)	.5780
Sulfuric acid ion (SO_4)	1.6482	Sulfuric anhydrid (SO_3)	1.3689
Silicic acid ion (SiO_3)	.0273	Silica (SiO_2)	.0216
Organic matter	trace	Carbonic anhydrid (CO_2)	.3051
		Water (H_2O)	.0624
		Oxygen equivalent	.1306
		Total	3.7242

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.9525	55.6355
Sodium sulfate (Na_2SO_4)	.2331	13.6154
Sodium hydrosulfate	trace	trace
Calcium sulfate ($CaSO_4$)	.8351	48.7782
Magnesium sulfate ($MgSO_4$)	1.1199	65.4133
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.5496	32.1021
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0124	.7243
Silica (SiO_2)	.0216	1.2616
Totals	3.7242	217.5304

69. Trans. Kan. Acad. Sci., vol. XII, p. 26.

Overbrook, Osage County.

SCHOOL DISTRICT NO. 96 WELL.

At Overbrook, Osage county, a well 144 feet deep was dug on the property of school district No. 96. The water was reached when it was down 122 feet. On account of the large amount of salt in the water, vessels in which it stood soon became incrusted. This well is located three miles south and one and one-half miles east of Overbrook. There are other wells within a mile of this which are deeper, but the water has an entirely different composition. The water attracted attention on account of the large amount of mineral salts which it contained, and the analysis given below shows that the water is not suitable to use as an ordinary potable water. The analysis is as follows:

SALINE-GYPSUM WELL.[70]

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	1.5841	Sodium oxid (Na_2O)	2.1352
Calcium (Ca)	.4288	Calcium oxid (CaO)	.6004
Magnesium (Mg)	.0357	Magnesium oxid (MgO)	.0596
Iron (Fe)	.0120	Iron oxid (Fe_2O_3)	.0154
Chlorin (Cl)	2.4220	Chlorin (Cl)	2.4220
Sulfuric acid ion (SO_4)	.9446	Sulfuric anhydrid (SO_3)	.7872
Silicic acid ion (SiO_3)	.0694	Silica (SiO_2)	.0548
		Carbonic anhydrid (CO_2)	.2445
		Water (H_2O)	.0559
		Oxygen equivalent	.5464
		Total	5.8286

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	3.9911	233.1201
Sodium bicarbonate ($NaHCO_3$)	.0451	2.6343
Calcium sulfate ($CaSO_4$)	1.1302	66.0151
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.3905	22.8091
Magnesium sulfate ($MgSO_4$)	.1788	10.4437
Silica (SiO_2)	.0548	3.2008
Totals	5.7905	338.2231

Analysis by E. H. S. Bailey and H. E. Davies.

70. Trans. Kan. Acad. Sci., vol. XV, p. 86.

Boon Mineral Well, Topeka.

This well is situated at 618 Fillmore street, just south of the dwelling of W. J. Boon. The well, which was dug in 1884, is sixty four feet deep, forty-eight feet being in the rock. The pump is arranged to deliver the water to a tank-wagon, from which it is sold to customers. Quite a business is carried on in the manufacture and sale of carbonated water as well as in the sale of natural water to customers in the city.

BOON MINERAL WELL.

Grams per liter.

IONS.	
Sodium (Na)	1.0310
Calcium (Ca)	.0958
Magnesium (Mg)	.0439
Chlorin (Cl)	1.4240
Sulfuric acid ion (SO_4)	.2602
Carbonic anhydrid (CO_2)	.0742
Silicic acid ion (SiO_3)	.0005

RADICALS.	
Sodium oxid (Na_2O)	1.3912
Calcium oxid (CaO)	.1341
Magnesium oxid (MgO)	.0452
Chlorin (Cl)	1.4240
Sulfuric anhydrid (SO_3)	.3718
Carbonic anhydrid (CO_2) (Free and combined.)	3.2236
Silica (SiO_2)	trace
Organic matter	3.0000
Oxygen equivalent	.3218
Total	9.2681

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	2.3493	137.2
Sodium sulfate (Na_2SO_4)	.3299	19.2
Calcium sulfate ($CaSO_4$)	.3160	18.4
Calcium carbonate ($CaCO_3$)	.0074	.4
Magnesium carbonate ($MgCO_3$)	.1355	6.8
Silica (SiO_2)	trace	trace
Organic matter	3.0000	173.0
Free carbonic anhydrid (CO_2)	3.1300	182.4
Totals	9.2681	541.4

Analysis by J. T. Lovewell.

Phillips's Mineral Spring, Topeka.

At 612 West Eighth street, in the city of Topeka, is situated a mineral spring that has attracted considerable attention. This spring or well is thirteen feet and four inches in depth, and the water rises within five feet of the surface. The water is brought to the surface by means of a chain pump, and is daily delivered to customers throughout the city. The well is covered by a small building. The analysis of this water was made in April, 1888. Another analysis of the same water, made independently at the same time, by W. B. Church, of Topeka, formerly chemist of the A. T. & S. F. railway, gave results that substantially agreed with those given below:

TOPEKA (PHILLIPS'S MINERAL SPRING).

Grams per liter.

IONS.		RADICALS.	
Potassium (K)	trace	Potassium oxid (K_2O)	trace
Sodium (Na)	.5880	Sodium oxid (Na_2O)	.7933
Calcium (Ca)	.3304	Calcium oxid (CaO)	.4625
Magnesium (Mg)	.1004	Magnesium oxid (MgO)	.2090
Iron (Fe)	.0014	Iron oxid (FeO)	.0017
Chlorin (Cl)	.3727	Chlorin (Cl)	.3727
Sulfuric acid ion (SO_4)	1.2352	Sulfuric anhydrid (SO_3)	1.0293
Silicic acid ion (SiO_3)	.0198	Silica (SiO_2)	.0158
		Carbonic anhydrid (CO_2)	.7200
		Water (H_2O)	.1470
		Oxygen equivalent	.0842
		Total	3.6670

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium sulfate (Na_2SO_4)	1.0702	62.5104
Sodium bicarbonate ($NaHCO_3$)	trace	trace
Sodium chlorid (NaCl)	.6142	35.8754
Potassium sulfate (K_2SO_4)	trace	trace
Calcium sulfate ($CaSO_4$)	.7250	42.3472
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.4748	27.7331
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.7628	44.5551
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0042	.2453
Silica (SiO_2)	.0158	.9228
Total mineral matter	3.6670	214.1893

Free carbonic-acid gas abundant.

Temperature........... 17° C. (62.6° F.)

Analysis by E. H. S. Bailey.

COMPARISON OF SIMILAR WATERS.

Grains per gallon.

Grand Rapids, Mich., Butterworth Springs.

Analysis by S. P. Duffield.

Sodium chlorid	12.728	Magnesium carbonate	3.456
Sodium carbonate	3.472	Ferrous carbonate	.704
Potassium chlorid	9.816	Alumina	.408
Calcium chlorid	6.104	Silica	.512
Calcium carbonate	5.792	Organic matter and loss	.664
Calcium sulfate	75.136	Total	160.648
Magnesium chlorid	41.856		

French Lick Springs, Indiana, Proserpine Spring.

Analysis by J. G. Rogers.

Sodium chlorid	90.92	Calcium sulfate	141.00
Sodium carbonate	10.52	Magnesium chlorid	8.05
Sodium sulfate	36.72	Magnesium sulfate	29.33
Potassium chlorid	5.01	Magnesium carbonate	4.50
Calcium carbonate	20.29	Iron carbonate	2.49
		Silica	1.69
		Total	350.52

Carbon dioxid........ 10.116 cubic inches.
Hydrogen sulfid........ 17.000 cubic inches.

Sandwich Springs, Ontario, Canada.

Analysis by S. P. Duffield.

Sodium chlorid	.560	Calcium chlorid	.056
Sodium carbonate	48.560	Magnesium carbonate	12.944
Potassium carbonate	trace	Magnesium chlorid	153.760
Calcium carbonate	38.504	Silica	.112
Calcium sulfate	123.832	Total	378.328

Carbonic dioxid........ 10.00 cubic inches.
Hydrogen sulfid........ 37.76 cubic inches.
Nitrogen........ .72 cubic inches.

Friedrickshall; Saxe-Meiningen, Germany.

Analysis by Bauer.

Sodium chlorid	538.96	Magnesium chlorid	248.64
Sodium sulfate	363.84	Magnesium bromid	.16
Ammonium chlorid	.48	Magnesium carbonate	28.24
Potassium sulfate	.16	Magnesium sulfate	316.40
Calcium carbonate	.88	Aluminum chlorid	.56
Calcium sulfate	89.92	Silica	1.68
		Total	1559.92

Carbon dioxid........ 42.56 cubic inches.

A Comparison of the Most Important Constituents of the Waters of the *Chlor-sulfate* Group.

Grains per gallon.

Name.	Total solids.	Sodium chlorid.	Sodium sulfate.	Calcium sulfate.	Calcium bicarbonate.	Magnesium sulfate.	Magnesium bicarbonate.
Merrill	277	132	102	5	* 8	19	* 4
Great Bend	3721	3185	175	131	....	85	141
Waconda No. 1	1140	749	221	....	34	57	70
Waconda No. 2	1053	713	140	....	65	101	7
Mountain Dew	102	12	10	22	32	32	....
Lincoln No. 1	1287	890	172	56	....	22	113
Marion (upper)	217	55	13	48	32	65	....
Overbrook	338	233	....	66	22	10	....
Boon	541	137	19	18	....	....	* 6
Phillips	214	35	62	42	27	....	44
Grand Rapids	160	12	....	75	* 5	$MgCl_2$ 41	* 3
French Lick	350	90	36	141	* 20	29	* 4
Sandwich, Ont	378	48	....	123	* 38	$MgCl_2$ 153	* 13
Fried'ckshall, Ger.	1559	538	333	89	1	316	* 28

* Carbonate.

CHAPTER XIII.

The Carbonate Group.

Carbonated waters are perhaps the most numerous of any class. These include some very heavily charged with mineral matter which has been dissolved from the rocks or soil by the carbon dioxid dissolved in the water, and others that contain only small quantities of the bicarbonates, as they are called. Most of the ordinary spring waters which have a local reputation for great therapeutic virtues are of this class; those having an excess of sodium carbonate are also included in this group. These are called by many authors the "alkaline" class, because they include the alkaline carbonates, potassium, sodium, and lithium, as well as carbonates of the alkaline earths, calcium, magnesium, and strontium. These waters usually contain an excess of carbon-dioxid (carbonic-acid) gas, more than enough to keep the bases in solution. Lime and magnesia, it should be said, are dissolved by water surcharged with this gas, in accordance with the well-known reaction:

$$CaCO_3+H_2O+CO_2 = CaH_2\ (CO_3)_2.$$

When a water of this composition evaporates spontaneously, as in the roof of a cave, or when it is heated, the water and carbon dioxid are expelled, and the calcium carbonate is precipitated or separates out in accordance with the reaction:

$$CaH_2(CO_3)_2 = CaCO_3+H_2O+CO_2.$$

This accounts for the formation of stalactites and many similar deposits.

These waters usually have an alkaline or neutral reaction. If sodium carbonate is present, the reaction is strongly alkaline, since carbonic acid is a very weak acid.

The amount of carbon-dioxid gas dissolved in the Kansas waters is small; in fact, there are none of this class that corre-

spond with the waters of many localities that yield a sparkling and effervescent product. Some have attributed this excess of carbonic acid to the volcanic origin of a water.

This group is represented by the following waters:

Atchison, Dixon's spring.
Baxter Springs, Cherokee county, Nos. 2, 3, and 4.
Bonner Springs, Leavenworth county, Nos. 1, 2, and 3.
Chico spring, Cherokee county.
Chautauqua springs, Chautauqua county.
Coffeyville, Montgomery county.
Eagle springs, Doniphan county, Nos. 1 and 2.
Eudora, Douglas county.
Kickapoo springs, Leavenworth county.
Moodyville, Pottawatomie county.
Murphy's springs, Geary county.
Onaga, Hoover's spring, Pottawatomie county.
Ottawa, Sylvan springs, Johnson county.
Stanley spring, Johnson county.

Dixon's Spring.

In the city of Atchison, on South Sixth street, between Park and Spring streets, is a strongly flowing spring, which has had considerable local reputation for medicinal properties. From the time of the earliest settlers it has never been known to become dry, though it has a stronger flow after rains, but the water is never turbid. It flows from beneath the Oread limestone, with a flow of at least seven gallons per minute.

This water was formerly sold throughout the city, but on account of the fact that the spring is in a thickly populated locality it was thought probable that the water might be impure. The sanitary analysis seems to confirm this suspicion, and, furthermore, the determination of chlorin, made at different times, shows that the quantity is quite variable, thus indicating surface contamination.

The Dixon Spring.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.1110	Sodium oxid (Na_2O)	.1496
Potassium (K)	.0060	Potassium oxid (K_2O)	.0072
Ammonium (NH_4)	trace	Ammonia	trace
Calcium (Ca)	.1560	Calcium oxid (CaO)	.2184
Magnesium (Mg)	.0250	Magnesium oxid (MgO)	.0417
Iron (Fe)	.0060	Iron oxid (FeO)	.0077
Aluminum (Al)	trace	Aluminum oxid (Al_2O_3)	trace
Chlorin (Cl)	.0580	Chlorin (Cl)	.0580
Sulfuric acid ion (SO_4)	.1164	Sulfuric anhydrid (SO_3)	.0970
Phosphate ion (PO_4)	.0054	Phosphoric anhydrid (P_2O_5)	.0040
Nitrate ion (NO_3)	.1065	Nitric anhydrid (N_2O_5)	.0927
Nitrite ion (NO_2)	trace	Nitrous anhydrid (N_2O_3)	trace
Silicic acid ion (SiO_3)	.0376	Silica (SiO_2)	.0300
		Water (H_2O)	.0831
		Carbonic anhydrid (CO_2)	.4044
		Oxygen equivalent	.0130
		Total	1.1808

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium sulfate (Na_2SO_4)	.1076	6.2760
Potassium nitrate (KNO_3)	.0155	.9041
Sodium phosphate (Na_2HPO_4)	.0080	.4666
Sodium chlorid (NaCl)	.0956	5.5760
Sodium nitrate ($NaNO_3$)	.1329	7.7520
Calcium sulfate ($CaSO_4$)	.0618	3.6050
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.5582	32.5600
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.1522	8.8775
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0190	1.1080
Silica (SiO_2)	.0300	1.7500
Total mineral matter	1.1808	68.8752

Temperature . . . . . 13.3° C. (56° F.)
Specific gravity . . . . . 1.00078.

Analysis by E. B. Knerr.

Baxter Springs.

The Baxter chalybeate springs, in Cherokee county, on the St. Louis & San Francisco railroad, were for many years among the most noted of any in the state. The place is of great interest geologically on account of the fact that it is just in the edge of the Mississippian formation that extends from Missouri across the extreme southeastern corner of Kansas. The region is well watered by abundant springs, and drained by Spring river, that flows about eighteen miles through the state and thence southward into the territory. The city of Baxter Springs is six miles from the Missouri line and a mile and a half north of Indian Territory. On account of its peculiar situation, Baxter Springs has attained considerable commercial importance and carries on trade with the Indians in the vicinity.

The springs were developed in 1883, but the hotel is of an earlier date, belonging to the time when the city was known only as an important trading point. The streams of this section of the state are very clear, and the banks are well wooded, so that, since the surface of the country is very much broken by hills and valleys, it presents a marked difference in appearance from most other parts of the state. On both sides of the small branch that flows easterly through the city, as many as thirty springs have been discovered, many of which have an abundant flow of clear, sparkling water. Within a few hundred yards no less than ten excellent springs are to be seen.

A list of these springs, with the temperature as shown on September 4, 1898, is as follows:

No. 1. West pavilion, Iron spring, 16° C. (60.8° F.)
2. East pavilion, Medical spring, 17° C. (62.6° F.)
3. Spring in highway east of latter.
4. Mann spring, on right bank of creek, 17° C. (62.6° F.)
5. Doty spring, near residence of Mr. Doty, 19° C. (66.2° F.)
6. Spring in pier of bridge.
7. Spring in highway, north of No. 1.
8. Spring in rock near residence of Mr. Newhouse, 19° C. (66.2° F.)
9. Sulfur spring near the Scott property, 19° C. (66.2° F.)
10. Spring beside bridge pier northwest of schoolhouse, 20° C. (68° F.)

West Pavilion, Baxter Springs.

Bath-house, Baxter Springs.

IMPROVEMENTS.

Springs Nos. 1 and 2, as above noted, are situated in a small park. They are about 100 feet apart, and each is covered by a pavilion (Plate XXI.) The springs are walled up and cemented, and furnish an abundance of water, which is utilized very extensively by the people of the city. The flow of spring No. 1 is estimated at about 480 gallons per hour, and that of No. 2 about 160 gallons per hour. At the northeast corner of the park is a bath-house with several bath-rooms, arranged for the use of hot and cold water. The water is pumped from either of the springs, and stored in a tank in the upper part of the bath-house.

On account of a change of proprietors, this resort was not in operation during the summer of 1898, nor has it been since that time. At some seasons of the year, especially during the summer, these springs are used by the people of the vicinity, and in fact spring No. 1 may be regarded as the source of city supply for good, wholesome drinking water. Spring No. 2 furnishes water that has been shipped quite extensively, but the water of No. 1 is said to contain so much iron that it deposits after standing a short time, so that, without special arrangements for carbonating, it cannot be conveniently shipped. The following analyses are from samples taken personally in June, 1901:

BAXTER SPRINGS NO. 2, "MEDICAL SPRING."

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0120	Sodium oxid (Na_2O)	.0161
Potassium (K)	.0042	Potassium oxid (K_2O)	.0050
Lithium (Li)	trace	Lithium oxid (Li_2O)	trace
Calcium (Ca)	.1260	Calcium oxid (CaO)	.1763
Magnesium (Mg)	.0054	Magnesium oxid (MgO)	.0090
Iron (Fe)	.0036	Iron oxid (FeO)	.0046
Chlorin (Cl)	.0162	Chlorin (Cl)	.0162
Sulfuric acid ion (SO_4)	.1416	Sulfuric anhydrid (SO_3)	.1180
Silicic acid ion (SiO_3)	.0149	Silica (SiO_2)	.0132
		Water (H_2O)	.0368
		Carbonic anhydrid (CO_2)	.1803
		Oxygen equivalent	.0036
		Total	.5719

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0203	1.1857
Sodium sulfate (Na_2SO_4)	.0122	.7126
Potassium chlorid (KCl)	.0080	.4673
Lithium bicarbonate ($LiHCO_3$)	trace	trace
Calcium sulfate ($CaSO_4$)	.1584	9.2522
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.3214	18.7730
Magnesium sulfate ($MgSO_4$)	.0270	1.5770
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0115	.6717
Silica (SiO_2)	.0132	.7710
Totals	.5720	33.4105

Analysis by E. B. Knerr.

BAXTER SPRINGS, NO. 3, DOTY'S SPRING.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0078	Sodium oxid (Na_2O)	.0105
Potassium (K)	.0063	Potassium oxid (K_2O)	.0076
Lithium (Li)	.0002	Lithium oxid (Li_2O)	.0003
Calcium (Ca)	.1118	Calcium oxid (CaO)	.1568
Magnesium (Mg)	.0060	Magnesium oxid (MgO)	.0101
Iron (Fe)	.0027	Iron oxid (FeO)	.0034
Chlorin (Cl)	.0101	Chlorin (Cl)	.0101
Nitrous acid ion (NO_2)	.0003	Nitrous anhydrid (N_2O_5)	.0002
Sulfuric acid ion (SO_4)	.1345	Sulfuric anhydrid (SO_3)	.1121
Silicic acid ion (SiO_3)	.0147	Silica (SiO_2)	.0131
		Water (H_2O)	.0323
		Carbonic anhydrid (CO_2)	.1590
		Oxygen equivalent	.0023
		Total	.5132

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0076	.4422
Sodium sulfate (Na_2SO_4)	.0147	.8587
Potassium chlorid (KCl)	.0116	.6743
Potassium nitrite (KNO_2)	.0006	.0355
Lithium bicarbonate ($LiHCO_3$)	.0015	.0875
Calcium sulfate ($CaSO_4$)	.1422	8.2950
Calcium bicarbonate ($CaH_2(CO_3)_2$	.2832	16.5100
Magnesium sulfate ($MgSO_4$)	.0302	1.7620
Iron bicarbonate ($FeH_2(CO_3)_2$	.0084	.4900
Silica (SiO_2)	.0132	.7700
Totals	.5132	29.9252

Analysis by E. B. Knerr.

BAXTER SPRINGS, NO. 4, MANN SPRING.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0069	Sodium oxid (Na_2O)	.0093
Potassium (K)	.0026	Potassium oxid (K_2O)	.0032
Lithium (Li)	.0008	Lithium oxid (Li_2O)	.0018
Calcium (Ca)	.1244	Calcium oxid (CaO)	.1741
Magnesium (Mg)	.0005	Magnesium oxid (MgO)	.0008
Iron (Fe)	.0017	Iron oxid (FeO)	.0022
Chlorin (Cl)	.0222	Chlorin (Cl)	.0222
Nitric acid ion (NO_3)	.0089	Nitric anhydrid (N_2O_5)	.0066
Nitrous acid ion (NO_2)	trace	Nitrous anhydrid (N_2O_3)	trace
Sulfuric acid ion (SO_4)	.1139	Sulfuric anhydrid (SO_3)	.0949
Silicic acid ion (SiO_3)	.0192	Silica (SiO_2)	.0152
		Water (H_2O)	.0338
		Carbonic anhydrid (CO_2)	.1608
		Oxygen equivalent	.0050
		Total	.5199

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0176	1.0280
Potassium nitrite (KNO_2)	trace	trace
Potassium nitrate (KNO_3)	.0068	.3972
Lithium bicarbonate ($LiHCO_3$)	.0080	.4673
Calcium nitrate ($Ca(NO_3)_2$)	.0062	.3621
Calcium chlorid ($CaCl_2$)	.0180	1.0514
Calcium sulfate ($CaSO_4$)	.1587	9.2696
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.2817	16.4541
Magnesium sulfate ($MgSO_4$)	.0024	.1402
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0053	.3096
Silica	.0152	.8878
Totals	.5199	30.3673

Analysis by E. B. Knerr.

The Springs Hotel, Baxter Springs.

Group of Springs, Bonner Springs.

Bonner Springs.

In Wyandotte county, at the northern end of the beautiful stretch of the Kaw river running northeast, is situated the Bonner Springs resort. This has been well known for many years. As originally settled it was called Tiblow, after an Indian chief, but when the proposition was made to make of it an important suburban resort for Kansas City, the present name, from Robert Bonner, was given it. Bonner Springs is seventeen miles west of Kansas City, on the Union Pacific railroad at the crossing of a branch of the Atchison, Topeka & Santa Fe railway running from Kansas City to Leavenworth; so it is very accessible from all directions. On account of the well-kept park in which the springs are situated, Bonner Springs has become a favorite camp-meeting resort. The park is not public property, but is owned by J. W. McDanield.

In the valley of the small creek that flows into the Kaw river just above the town, there are found as many as twenty springs, and at the head of these there is a lake, also fed by springs. Four of them are picturesquely grouped in the upper park, just below the camping-ground, and there are several in the lower park.

IMPROVEMENTS.

The improvements are of considerable importance. In addition to the lake, which furnishes abundant facilities for boating, there are a large pavilion and several permanent buildings designed for the use of camp-meeting associations, and others who may tent upon these grounds. The trees are large, and many belong to the first growth. In the lower park a building has been erected for the protection of visitors from the weather, and in connection with this there is a large stand for the sale of refreshments. Near this building is a pavilion built over two of the most valuable springs. The water of one of these is carried by a pipe-line to the pump-house in the valley below the "Lodge," where a pump run buy a windmill or a gasoline-engine elevates the water to the top of the "Lodge."

The sanitarium is some distance south of the park, and, situ-

ated as it is, upon something of an elevation, it commands a beautiful view to the south across the Kaw river. The building contains fifty rooms, with 400 feet of verandas. It has steam heat, and is furnished with all modern conveniences. No special bath-houses are provided for using the spring water. The sanitarium is owned and managed by Dr. M. P. Sexton, and is at present devoted especially to the treatment of nervous and mental diseases. On account of the proximity of the sanitarium to Kansas City, it affords a convenient suburban home where patients may be kept quiet, and away from the noise and bustle of the city. No attempt has been made to ship the water from Bonner Springs, although at some seasons of the year the quantity is ample for this purpose. The analyses of seven of the springs, made in 1884, and published in bulletin of the United States Geological Survey No. 32, is as follows:

BONNER SPRINGS, NO. 1.

IONS.	Grams per liter.
Calcium (Ca)	.0926
Magnesium (Mg)	.0268
Iron (Fe)	.0112
Chlorin (Cl)	.0082
Sulfuric acid ion (SO_4)	.0315
Silicic acid ion (SiO_3)	.0107
Phosphoric acid ion (PO_4)	trace

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Calcium chlorid ($CaCl_2$)	.0129	.751
Calcium sulfate ($CaSO_4$)	.0447	2.612
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.3126	18.261
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.1630	9.525
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0361	2.107
Silica (SiO_2)	.0085	.496
Phosphoric acid	trace	trace
Organic matter	small amt.	small amt.
Totals	.5778	33.752

Analysis by Wm. Jones, M. D.

Pavilion, Bonner Springs Park.

Bonner Springs Lake.

BONNER SPRINGS, NO. 2.

IONS.	Grams per liter.
Calcium (Ca)	.0923
Magnesium (Mg)	trace
Iron (Fe)	.0012
Chlorin (Cl)	.0114
Silicic acid ion (SiO_3)	.0082
Phosphoric acid ion (PO_4)	trace
Total	.1131

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Calcium chlorid ($CaCl_2$)	.0179	1.042
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.3729	21.782
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	trace	trace
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0037	.217
Phosphoric acid	trace	trace
Silica (SiO_2)	.0065	.381
Organic matter	small amt.	small amt.
Total	.4010	23.422

Analysis by Wm. Jones, M. D.

BONNER SPRINGS, NO. 3.

IONS.	Grams per liter.
Sodium (Na)	.5636
Calcium (Ca)	.0485
Magnesium (Mg)	.0374
Chlorin (Cl)	.1301
Sulfuric acid ion (SO_4)	trace
Phosphoric acid ion (PO_4)	trace

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.2105	12.293
Sodium bicarbonate ($NaHCO_3$)	1.7493	102.178
Calcium chlorid ($CaCl_2$)	trace	trace
Calcium sulfate ($CaSO_4$)	trace	trace
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.1952	11.403
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.2230	13.024
Phosphoric acid	trace	trace
Organic matter	small amt.	small amt.
Totals	2.3780	138.898

Analysis by Wm. Jones, M. D.

Bonner Springs Sanitarium.

Chautauqua Springs Hotel.

Chautauqua Springs.

In Chautauqua county there is a pure spring of water which has attracted considerable attention. It flows from beneath a sandstone rock in a little valley south of the village of Chautauqua Springs. Few improvements have been made, with the exception of erecting a spring-house. This region is much diversified by hills and valleys, and the streams are clear and sparkling. In this respect the region differs from most of the Kansas mineral-spring localities. This water belongs to that class of comparatively pure waters or "soft" waters referred to in chapter XVIII. Such waters are very useful when it is of advantage to the patient to drink copiously, and when he does not desire the effect of any mineral salts. As the water is free from large quantities of salts of lime and magnesium, which are so abundant in Kansas, it may in many cases be very beneficial to patients. Chautauqua may be reached by the A. T. & S. F. railroad.

CHAUTAUQUA SPRINGS.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0270	Sodium oxid (Na_2O)	.0364
Calcium (Ca)	.0367	Calcium oxid (CaO)	.0514
Magnesium (Mg)	.0084	Magnesium oxid (MgO)	.0140
Iron (Fe)	.0024	Iron oxid (FeO)	.0031
Chlorin (Cl)	.0342	Chlorin (Cl)	.0342
Sulfuric acid ion (SO_4)	.0490	Sulfuric anhydrid (SO_3)	.0409
Silicic acid ion (SiO_3)	.0353	Silicic anhydrid (SiO_2)	.0279
		Carbonic anhydrid (CO_2)	.0799
		Water (H_2O)	.0162
		Oxygen equivalent	.0077
		Total	.2963

Hypothetically combined as follows:

	Grams per liter.	Grains. per gallon.
Sodium chlorid (NaCl)	.0565	3.300
Sodium bicarbonate ($NaHCO_3$)	.0174	1.019
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.0660	3.860
Calcium sulfate ($CaSO_4$)	.0695	4.051
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.0512	2.994
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0078	.456
Silica (SiO_2)	.0279	1.628
Totals	.2963	17.308

Analysis by E. H. S. Bailey and E. C. Franklin.

Coffeyville Well.

This well is situated on the property of Joseph Kloehr, one and one half-miles east of Coffeyville, in the Verdigris river bottom, and a quarter of a mile from that stream. The heavy timber of the vicinity adds much to the attractiveness of the situation. The well is dug sixteen feet deep, and from the bottom a pipe is driven sixteen feet and eight inches into the sand and gravel. Coffeyville is on the lines of the Missouri Pacific, the Atchison, Topeka & Santa Fe, and the Missouri, Kansas & Texas railroads.

IMPROVEMENTS.

The improvements are a driveway from the main road, leading to the new two-story building arranged as a water-cure establishment for the accommodation of boarders. The water is sold to the people in the vicinity.

The analysis is as follows:

COFFEYVILLE WELL.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0088	Sodium oxid (Na_2O)	.0118
Calcium (Ca)	.1661	Calcium oxid (CaO)	.2325
Magnesium (Mg)	.0357	Magnesium oxid (MgO)	.0595
Iron (Fe)	.0095	Iron Oxid (FeO)	.0122
Chlorin (Cl)	.0135	Chlorin (Cl)	.0135
Sulfuric acid ion (SO_4)	.0276	Sulfuric anhydrid (SO_3)	.0230
Silicic acid ion (SiO_3)	.0304	Silicic anhydrid SiO_2)	.0240
		Carbonic anhydrid (CO_2)	.4859
		Water (H_2O)	.0993
		Oxygen equivalent	.0031
		Total	.9586

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0223	1.304
Calcium sulfate ($CaSO_4$)	·0391	2.282
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.6259	36.559
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.2172	12.686
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0301	1.755
Silica (SiO_2)	.0240	1.405
Totals	.9586	55.991

Analysis by E. H. S. Bailey.

Chautauqua Springs.

Eagle Springs House.

Eagle Springs (Highland Station).

In the extreme eastern part of Doniphan county, surrounded on three sides by a bend of the Missouri river, is a peculiar section of country covered with high, rounded elevations, separated by deep valleys. The hills become higher in the vicinity of the river on the east, forming the so-called bluffs. These are well wooded, and it is interesting to note that there is here a greater variety of trees than is found in other sections of the state. Much of this timber has been recently cut, however, to give place to orchards which thrive so well in this section. The apple and peach especially seem to be well adapted to this soil, which is composed largely of gravel and clay, and it is even asserted by some that apples grown upon these bluffs have a better flavor than those grown upon prairie soil. From the bluffs on the east a very extensive view of the windings of the Missouri river may be obtained; this view extends from St. Joseph, Mo., northward for perhaps forty miles, and to the south and west the high prairie uplands are visible. This section of Doniphan county is drained by Wolf river, which flows northward and empties into the Missouri near White Cloud. Among the hills east of Wolf river, a short distance from the Burlington & Missouri River railroad (Highland Station), are situated Eagle Springs, which were developed in 1882.

IMPROVEMENTS.

There is here a hotel having a capacity for forty guests, which is owned and managed by Pryor Plank, a bath-house, two cottages, and a fine artificial lake well stocked with fish. During the summer a resident physician may be usually found at the Eagle Springs hotel. The two most important springs are the upper spring, which has a flow of not over thirty gallons per hour, and the lower spring, which is quite near the bath-house, and has a flow of 300 gallons per hour and a temperature of 13° C. (55.4° F.)

EAGLE SPRINGS, NO. 1, LOWER SPRING.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0055	Sodium oxid (Na_2O	.0084
Calcium (Ca)	.1022	Calcium oxid (CaO)	.1431
Magnesium (Mg)	.0374	Magnesium (MgO)	.0623
Iron (Fe)	.0051	Ferric oxid (Fe_2O_3)	.0072
Chlorin (Cl)	.0096	Chlorin (Cl)	.0096
Sulfuric acid ion (SO_4)	.0122	Sulfuric anhydrid (SO_3)	.0102
Silicic acid ion (SiO_3)	.0330	Silica (SiO_2)	.0261
		Carbonic anhydrid (CO_2)	.3583
		Water (H_2O)	.0730
		Oxygen equivalent	.0022
		Total	.6960

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0158	.9229
Calcium sulfate ($CaSO_4$)	.0173	1.0105
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.3934	22.9784
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.2274	13.2825
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0160	.9346
Silica (SiO_2)	.0261	1.5247
Totals	.6960	40.6536

Temperature .... 11.8° C. (53.4° F.)

Analysis by E. H. S. Bailey and D. F. McFarland.

EAGLE SPRINGS, NO. 2, UPPER SPRING.

Grams per liter.

IONS.	
Sodium (Na)	.0232
Potassium (K)	.0647
Calcium (Ca)	.0617
Magnesium (Mg)	.0186
Iron and aluminum (Fe and Al),	.0007
Chlorin (Cl)	.0006
Silicic acid ion (SiO_3)	.0241
Sulfuric acid ion (SO_4)	.0101

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0010	.0575
Sodium bicarbonate ($NaHCO_3$)	.0530	3.1507
Potassium sulfate (K_2SO_4)	.0181	1.0527
Potassium bicarbonate ($KHCO_3$)	.1015	5.9357
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.2523	16.0269
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.1135	6.6376
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0022	.1277
Silica (SiO_2)	.0191	1.1197
Organic matter	.0167	.9797
Totals	.5774	35.0882

Analysis by Walter C. Brown, Chicago.

Eudora Mineral Springs, Douglas County.

There were four springs developed here about ten years ago. The principal springs are situated on the right bank of the Wakarusa, a few rods above the crossing of the Atchison, Topeka & Santa Fe railroad. They are on the first terrace of the river, and are walled with brick and cement. The surrounding grounds were improved by cutting out the timber and constructing stairways, walks, and pavilions. Very little attention has recently been paid to this property, though formerly it attracted picnic and excursion parties. The analysis of spring No. 2 is given below. The water of the other springs is quite similar, although the amount of iron differs in the different waters. These might with equal propriety be classified as chalybeate springs.

EUDORA MINERAL SPRING NO. 2.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0201	Sodium oxid (Na_2O)	.0270
Potassium (K)	.0052	Potassium oxid (K_2O)	.0063
Calcium (Ca)	.1491	Calcium oxid (CaO)	.2095
Magnesium (Mg)	.0155	Magnesium oxid (MgO)	.0258
Iron (Fe)	.0140	Iron oxid (FeO)	.0180
Manganese (Mn)	trace	Manganese oxid (MnO)	trace
Chlorin (Cl)	.0049	Chlorin (Cl)	.0049
Sulfuric acid ion (SO_4)	.0302	Sulfuric anhydrid (SO_3)	.0252
Silicic acid ion (SiO_3)	.0420	Silicic anhydrid (SiO_2)	.0332
		Organic and volatile matter	.0261
		Carbonic anhydrid (CO_2)	.4176
		Water (H_2O)	.0856
		Oxygen equivalent	.0011
		Total	.8781

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0081	.472
Sodium bicarbonate ($NaHCO_3$)	.0601	3.510
Potassium sulfate (K_2SO_4)	.0117	.683
Calcium sulfate ($CaSO_4$)	.0337	1.968
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.5664	33.083
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.0943	5.502
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0445	2.600
Manganese bicarbonate ($MgH_2(CO_3)_2$)	trace	trace
Silica (SiO_2)	.0332	1.941
Organic and volatile matter	.0261	1.520
Totals	.8781	51.279

Analysis by E. H. S. Bailey.

Kickapoo Springs, Leavenworth County.

These springs are situated about seven miles northwest of the city of Leavenworth, on the farm of George W. Few. They are located in a valley where the land overlooks the Missouri river bluffs, and on the south is a range of hills. There are three springs in the group, all of which are more or less chalybeate. No. 1, the analysis of which is given below, has been carefully boxed, and is five and one-half feet in depth. The waters from all these springs are clear and sparkling when first drawn, but deposit the iron hydrate in the stream below for a long distance. This is of course due to the escape of carbon-dioxid gas, as has been previously noticed.

Stone implements, such as arrow-heads and spear-heads that areoften found near the springs, indicate that this locality was a favorite camping-ground for the Indians, and, as the Kickapoos were the last tribe having a reservation in this vicinity, the springs have been named after them. No improvements have been made in the property and the water is not shipped.

The composition of spring No. 1 is as follows:

KICKAPOO SPRINGS.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0096	Sodium oxid (Na_2O)	.0130
Potassium (K)	.0009	Potassium oxid (K_2O)	.0012
Calcium (Ca)	.0636	Calcium oxid (CaO)	.0891
Magnesium (Mg)	.0132	Magnesium oxid (MgO)	.0220
Iron (Fe)	.0007	Iron oxid (FeO)	.0009
Aluminum (Al)	.0006	Aluminum oxid (Al_2O_3)	.0011
Chlorin (Cl)	.0029	Chlorin (Cl)	.0029
Sulfuric acid (ion) (SO_4)	.0238	Sulfuric anhydrid (SO_3)	.0199
Nitric acid ion (NO_3)	trace	Nitric anhydrid (N_2O_3)	trace
Silicic acid ion (SiO_3)	.0320	Silica (SiO_2)	.0252
		Carbonic anhydrid (CO_2)	.1845
		Water (H_2O)	.0376
		Oxygen equivalent	.0004
		Total	.3970

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Potassium sulfate (K_2SO_4)	.0029	.169
Sodium chlorid (NaCl)	.0049	.286
Sodium bicarbonate ($NaHCO_3$)	trace	trace
Sodium nitrate ($NaNO_3$)	trace	trace
Sodium sulfate (Na_2SO_4)	.0238	1.394
Calcium sulfate ($CaSO_4$)	.0088	.513
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.2468	14.415
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.0813	4.748
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0022	.128
Aluminum oxide (Al_2O_3)	.0011	.064
Silica (SiO_2)	.0252	1.471
Totals	.3970	23.188

Analysis by E. H. S. Bailey.

Moodyville Springs.

At Moodyville, in Pottawatomie county, about four miles northeast of Westmoreland, in Rock creek bottom, on the Westmoreland branch of a road connecting with the Leavenworth, Kansas & Western railroad at Blaine, are situated several springs that have obtained a local reputation. These springs are the property of E. M. Moody, and are situated at the base of a limestone bluff surrounded by a fine grove of natural timber.

IMPROVEMENTS.

An avenue bordered with large trees connects the springs property with the main road. Some years ago a hotel was built on the land just west of the grove, and extensive improvements, including walks, fountains, swinging bridges, etc., were made on the property. Recently, however, no attempt has been made to keep the property in repair. On the bluff to the east of the spring is a so-called Indian mound, and a lookout has been built here which commands an extensive prospect over the surrounding territory. Some rocks tumbled together on the side of the bluff near by form an interesting cave. The water of the main spring has a temperature of 12.2° C. (54° F.) and a flow of 360 gallons per hour. It has a specific gravity of 1.00395. The qualitative analysis made by J. R. Eaton, chemist of William Jewell College, Liberty, Mo., showed calcium carbonate, magnesium carbonate, maagnesium sulfate, sodium sulfate, sodium chlorid, iron carbonate, silica, alumina, and a trace of organic matter. The water contains an abundance of free carbonic-acid gas, and, when concentrated, gives an alkaline reaction.

Moodyville Springs.

Murphy's Springs.

Murphy's Springs, Junction City, Geary County.

These springs, of which there are seven in the group, are situated six miles southwest of Junction City, near Kansas Falls station, on the line of the Union Pacific railroad. No improvements except the building of a spring-house have been made. The water is forced by a windmill pump to the dwelling-house of Charles Murphy, about a quarter mile distant. There is an abundance of excellent water here, but it is only utilized for domestic and stock-feeding purposes.

MURPHY'S SPRINGS.[70]

IONS.	Grams per liter.
Sodium (Na)	.0163
Calcium (Ca)	.0557
Magnesium (Mg)	.0147
Iron (Fe)	trace
Aluminum (Al)	trace
Silicic acid ion (SiO_3)	.0213

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium bicarbonate ($NaHCO_3$)	.0597	3.475
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.2251	13.149
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.0899	5.243
Iron and aluminum oxids (Fe_2O_3, Al_2O_3)	trace	trace
Silica (SiO_2)	.0168	.982
Totals	.3915	22.849

Analysis by Barnes and Sim.

70. Bull. U. S. Geol. Surv. No. 32, p. 173.

Hoover's Spring, Onaga.

Interior of Spring-house, Hoover's Spring.

Hoover's Spring, Onaga, Pottawatomie County.

In the northern part of Pottawatomie county, about one-half mile north of the village of Onaga, which is accessible by the Kansas City, Leavenworth & Western railway, is a mineral spring owned and managed by Henry Hoover. The spring is in a depression east of the owner's residence, and in the vicinity, both north and west, are hills overlooking the valley of the Vermillion on the east. The whole region is diversified by numerous hills and valleys, and is well watered and timbered. Hoover's spring, which is 200 feet above the Vermillion, has been excavated twelve feet, to the clay. It was then walled and cemented to a point three feet above the floor of the spring-house. Clear water, which may be seen to bubble from the sand at the bottom, is conducted away to a cement reservoir about twenty feet distant. No attempt is made to utilize the water, except by local patrons and an occasional shipment of a few gallons. The flow is 180 gallons per hour. The composition of the water is as follows:

HOOVER'S SPRING, ONAGA.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0049	Sodium oxid (Na_2O)	.0066
Calcium (Ca)	.0273	Calcium oxid (CaO)	.0383
Magnesium (Mg)	.0199	Magnesium oxid (MgO)	.0333
Iron (Fe)	.0029	Iron oxid (FeO)	.0038
Chlorin (Cl)	.0076	Chlorin (Cl)	.0076
Sulfuric acid ion (SO_4)	.0141	Sulfurid anhydrid (SO_3)	.0118
Silicic acid ion (SiO_3)	.0308	Silica (SiO_2)	.0244
		Carbonic anhydrid (CO_2)	.1258
		Water (H_2O)	.0253
		Oxygen equivalent	.0017
		Total	.2752

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0125	.7301
Calcium sulfate ($CaSO_4$)	.0200	1.1682
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.0873	5.0992
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.1216	7.1027
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0094	.5490
Silica (SiO_2)	.0244	1.4252
Totals	.2752	16.0744
Temperature	16.6° C. (61.9° F.)	

Analysis by E. H. S. Bailey.

Sylvan Springs, Ottawa.

Mineral Well, Iola.

Sylvan Springs, Ottawa.

These springs are situated about two miles northwest of Eight Mile creek, a branch of the Marais des Cygnes. There is a ford at this point over the creek, and a drive has been cut through the timber, so that the springs are accessible. The springs are the property of the estate of S. E. Allison, and perhaps $100 was spent in the improvements noted. The water of the main spring comes out of the rock on a level with the creek, but when confined it rises above that level, so that by carefully walling up and cementing about the spring an abundant supply is retained. In order to obtain the water conveniently a platform has been built above the spring, and the water is brought to this platform by means of a pump.

The flow is about 200 gallons per hour in the dryest weather. Within a few rods are several other springs, but the one of which the analysis has been made has the greatest flow. Within the last five years the water has been hauled to Forest Park Ottawa, and placed in permanent tanks for use during the Chautauqua assembly, which meets for about two weeks in July of each year. The water has found quite an extensive use locally, but has not been shipped.

SYLVAN SPRING, OTTAWA.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0242	Sodium oxid (Na_2O)	.0325
Calcium (Ca)	.1238	Calcium oxid (CaO)	.1730
Magnesium (Mg)	.0260	Magnesium oxid (MgO)	.0437
Iron (Fe)	.0008	Iron oxid (FeO)	.0011
Chlorin (Cl)	.0371	Chlorin (Cl)	.0371
Sulfuric acid ion (SO_4)	.0371	Sulfuric anhydrid (SO_3)	.0308
Silicic acid ion (SiO_3)	.0235	Silica (SiO_2)	.0186
		Carbonic anhydrid (CO_2)	.3362
		Water (H_2O)	.0679
		Oxygen equivalent	.0083
		Total	.7326

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0613	3.575
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.5003	29.221
Magnesium sulfate ($MgSO_4$)	.0461	2.688
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.1037	6.052
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0026	.155
Silica (SiO_2)	.0186	1.085
Totals	.7326	42.776

Temperature .... 20° C. (68° F.)

Analysis by E. H. S. Bailey.

Stanley Spring, Johnson County.

The water of a spring on the farm of Freeman Shreve, at Stanley, has been used with considerable success by the local physicians. It has a flow of about twelve barrels per hour. The spring has been dug out to the depth of five feet and securely boxed. This water gives upon evaporation 18.3 grains of mineral matter per gallon. This consists of calcium, magnesium, sodium and iron carbonates, with some sulfates. It belongs to the light carbonate group of waters.

COMPARISON OF SIMILAR WATERS.

Grains per gallon.

Waukesha, Wis., Bethesda Spring.

Analysis by C. F. Chandler.

Sodium chlorid	1.16	Iron bicarbonate	.04
Sodium bicarbonate	1.26	Aluminum oxid	.12
Sodium sulfate	.54	Silica	.74
Potassium sulfate	.46	Organic matter	1.98
Calcium bicarbonate	17.02	Total	35.71
Magnesium bicarbonate	12.39		

Napa Soda Springs, California, Pagoda Spring.

Analysis by Winslow Anderson.

Sodium chlorid	7.14	Magnesium bicarbonate	3.04
Sodium bicarbonate	12.95	Magnesium carbonate	21.76
Sodium carbonate	1.10	Ferrous carbonate	7.90
Sodium sulfate	1.62	Silica	.74
Potassium bicarbonate	trace	Alumina	.57
Calcium bicarbonate	.78	Organic matter	trace
Calcium carbonate	9.55	Total	67.15

Free carbon-dioxid gas .... 143.62 cubic inches.
Temperature of water .... 67.7° F.

Manitou, Colo., Manitou Soda Springs.

Analysis by Elwyn Waller.

Sodium chlorid	23.94	Magnesium carbonate	16.68
Sodium carbonate	40.66	Iron oxid	.02
Sodium sulfate	11.14	Alumina	.07
Potassium sulfate	10.68	Silica	2.49
Lithium carbonate	.71	Total	174.47
Calcium carbonate	69.08		

Free carbon-dioxid gas....................... abundant.

Highland Springs, California, Ems Spring.

Analysis by Winslow Anderson.

Sodium chlorid	1.76	Ferrous carbonate	1.53
Sodium bicarbonate	17.50	Manganese bicarbonate	trace
Sodium carbonate	2.45	Silica	7.23
Potassium bicarbonate	.78	Alumina	.12
Calcium bicarbonate	57.32	Organic matter	trace
Magnesium bicarbonate	66.55	Total solids	156.87
Magnesium carbonate	1.63		

Free carbon-dioxid gas............... 85.90 cubic inches.
Temperature of water................ 77° F.

Saratoga, New York, Vichy Spring.

Analysis by C. F. Chandler.

Sodium chlorid	128.69	Barium bicarbonate	.59
Sodium bicarbonate	82.87	Iron bicarbonate	.05
Sodium bromid	.99	Alumina	.48
Potassium chlorid	14.11	Silica	.76
Lithium bicarbonate	1.76	Total	367.32
Calcium bicarbonate	95.52		
Magnesium bicarbonate	41.50		

Carbon-dioxid gas .... 383.07 cubic inches.

Vichy, France, Grande Grille.

Analysis by Bouquet.

Sodium chlorid	7.827	Calcium bicarbonate	28.517
Sodium bicarbonate	319.442	Magnesium bicarbonate	20.187
Sodium sulfate	16.997	Ferrous bicarbonate	.260
Sodium phosphate	7.592	Silica	4.089
Sodium arsenite	.175	Total	427.680
Potassium bicarbonate	22.594		

Apollinaris, Neuenahar, Rhenish Prussia.

Analysis by Professor Bischof.

Sodium chlorid	28.56	Ferric oxid	1.20
Sodium carbonate	77.20	Alumina	1.20
Sodium sulfate	18.40	Silica	.48
Calcium carbonate	3.60	Total	157.76
Magnesium carbonate	27.12		

Free carbon-dioxid gas.............. 376.32 cubic inches.

A Comparison of the Waters of the *Carbonate* Group.

Grains per gallon.

NAME.	Total solids.	Sodium chlorid.	Sodium bicarbonate.	Calcium sulfate.	Calcium bicarbonate.	Magnesium bicarbonate.
Dixon	68	5	....	3	32	8
Baxter No. 2	33	1	....	9	18	....
Bonner No. 1	33	....	....	2	18	9
Bonner No. 3	138	12	102	trace	11	13
Chautauqua	17	3	1	4	3	3
Coffeyville	56	1	....	2	36	12
Eagle No. 1	40	1	....	1	23	13
Eagle No. 2	35	....	3	....	16	6
Eudora No. 2	51	....	3	2	33	5
Kickapoo	23	....	trace	....	14	5
Murphy	22	....	3	....	13	5
Hoover's	16	....	....	1	5	7
Sylvan	42	3	....	....	29	6
Waukesha, Wis	35	1	1	....	17	12
Manitou, Colo	174	24	40	....	* 69	* 16
Napa Soda, Cal	67	7	13	....	* 10	* 24
Highland, Cal	156	1	20	....	57	67
Apollinaris, Prussia	157	28	71	....	* 3	* 27

* Carbonate.

These waters in Kansas contain calcium and magnesium bicarbonates and little besides. Some chemists have reported sodium sulfate in some of the waters of this general class. It is apparent that the sodium bicarbonate, the ingredient that gives an alkaline quality to such waters, is usually absent, or only present in small quantities. There are waters in the state, like the Abilena, and a water from Cherryvale that has been recently analyzed, which do contain considerable sodium carbonate, but a very large quantity of some other ingredients entirely overshadows the sodium carbonate in those waters.

The total solids are usually low, and in fact so low that some of the waters mentioned might be considered in the soft-water group.

CHAPTER XIV.

The Chlor-Carbonate Group.

The waters of group IV, containing an excess of carbonic-acid gas, are not numerous in this section, neither are those containing the chlorids and large quantities of bicarbonates very abundant. The waters have the therapeutic properties of both the chlorids and the "calcic" waters, as they are called by some authors. These waters are largely represented, however, in other sections of the country and abroad. The strong taste of a pure brine, or of a brine containing sulfates, is modified by the presence of the calcium, magnesium, and sodium carbonate, and, in such waters as the Empire spring, at Saratoga Springs, it is modified by the great excess of carbonic-acid gas dissolved in the water.

This group is represented by the following waters:

Cherryvale well, Montgomery county.

Iola well, Allen county.

Miller's well, Norwood, Franklin county.

Paola well, Miami county.

Piqua, Woodson county.

Wyandotte, Wyandotte county, gas well.

Fort Scott artesian, Bourbon county.

Cherryvale Well, Montgomery County.

A sample of water has been received from Dr. M. A. Findley, of Cherryvale, that is of considerable interest. The water is from a well about three miles northwest of the city, near Drum creek. The well is bored, and the water is said to come from a depth of about 120 feet. A partial analysis of the water has been made, with the following result:

CHERRYVALE WELL.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.5910	Sodium oxid (Na_2O)	.7966
Calcium (Ca)	.0098	Calcium oxid (CaO)	.0138
Magnesium (Mg)	.0114	Magnesium oxid (MgO)	.0190
Iron (Fe)	.0031	Iron oxid (FeO)	.0040
Chlorin (Cl)	.5330	Chlorin (Cl)	.5330
Silicic acid ion (SiO_3)	.0148	Silicic anhydrid (SiO_2)	.0117
		Carbonic anhydrid (CO_2)	.5328
		Water (H_2O)	.1093
		Oxygen equivalent	.1210
		Total	1.8992

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid	.8810	51.459
Sodium bicarbonate	.8870	51.804
Calcium bicarbonate	.0405	2.388
Magnesium bicarbonate	.0690	4.024
Iron bicarbonate	.0100	.584
Silica	.0117	.684
Totals	1.8992	110.943

Analysis by E. H. S. Bailey and D. F. McFarland.

The Iola Mineral Well.

At Iola, in Allen county, there are a number of gas and mineral wells. This city may be easily reached by either the Missouri Pacific or the Atchison, Topeka & Santa Fe railroads.

The Ben Acres well antedates all such wells in the state, as it was bored in 1873, while prospecting for coal. With commendable perseverance the managers continued to bore, till they reached a depth of 626 feet, when it was noticed that the drill dropped twenty inches and water and gas were forced up. At 720 feet the drilling was discontinued. The water, which flowed at one time as much as ninety-five barrels a day, comes up intermittently, on account of the pressure of the gas. It is interesting to notice that within a few hundred rods of this well are some of the best gas wells of the state, and these early prospectors came very near making the discovery that has recently placed Iola among the first of the gas towns, and has brought

Hotel and Cottages, Iola.

Water-works Plant, Cherokee.

to the city so many smelters, brick plants, cement works, and other manufacturing industries.

Even in these early days the flow of gas from this well was noticed, and it was estimated that 5000 cubic feet was given off daily. At the present day wells in the vicinity yield gas at a pressure of 350 pounds to the square inch, from a depth of from 800 to 900 feet, and the yield from a single well is estimated at seven million cubic feet per day. Formerly considerable use was made of the water of the Iola well, and much was shipped elsewhere. Its use was especially recommended for bathing, and a commodious bath-house, with pumps and an arrangement for heating the water, was erected. The large building of Mr. Acres was used as a hotel and two cottages were occupied by boarders. The analysis of the water was made in 1876 by the late Prof. W. R. Kedzie,[71] then of Kansas Agricultural College. The temperature was 61° F. Its specific gravity was 1.0138.

Professor Patrick reports a small quantity of sodium sulfate, while the former analyst finds none. The amount of sodium bromid is reported as .04 grams per liter. The presence of the bromids and iodids in deep wells in this state is at present known to be not unusual. Brine flows from many of the gas wells that have been more recently bored in this county.

IOLA WELL.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.6580	Sodium oxid (Na_2O)	8.8804
Potassium (K)	.1921	Potassium oxid (K_2O)	.2313
Calcium (Ca)	.2565	Calcium oxid (CaO)	.3591
Magnesium (Mg)	.1035	Magnesium oxid (MgO)	.1722
Iron (Fe)	.0212	Iron oxid (FeO)	.0271
Chlorin (Cl)	10.3211	Chlorin (Cl)	10.3211
Silicic acid ion (SiO_3)	.0113	Silica (SiO_2)	.0103
		Suspended matter	.0428
		Organic matter	.0342
		Carbon dioxid	1.0530
		Water of combination	.1913
		Oxygen equivalent	2.4894
		Total	18.8334

71. Trans. Kan. Acad. Sci., vol. VI, pp. 58-61.

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid ($NaCl$)	16.6325	971.506
Sodium bromid ($NaBr$)	abundant	abundant
Sodium iodid (NaI)	trace	trace
Sodium bicarbonate ($NaHCO_3$)	.1396	8.158
Potassium chlorid (KCl)	.3066	17.909
Magnesium chlorid ($MgCl$)	.1250	7.305
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.4363	25.485
Calcium bicarbonate ($CaH_2(CO_3)_2$)	1.0389	60.687
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0672	3.929
Silica (SiO_2)	.0103	.602
Suspended matter	.0428	2.500
Organic matter	.0342	2.000
Totals	18.8334	1100.081

Analysis by W. R. Kedzie.

Miller's Well, Norwood, Franklin County.

This well is situated on the farm of George Miller, two miles west and one mile north of Norwood station, on the Atchison, Topeka & Santa Fe railroad. It is on high ground, and was bored almost entirely in shale. The depth is 250 feet.

The well was dug for fifty-three feet, and then a boring was made, and cased with six-inch galvanized-iron pipe. When the water was struck it rose to the height of 125 feet in the tube. The capacity of the well is at least twenty barrels per day, and the water is raised by means of a windmill. The water does not seem to disagree with stock, although there is enough salt in it to give it a strong saline taste. The temperature is about 60° F. No attempt has been made to place the water upon the market, but it has a local reputation as a cathartic.

MILLER'S WELL, NORWOOD.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	5.3881	Sodium oxid (Na_2O)	7.2616
Calcium (Ca)	.2360	Calcium oxid (CaO)	.3298
Magnesium (Mg)	.0996	Magnesium oxid (MgO)	.1661
Iron (Fe)	.0048	Iron oxid (FeO)	.0062
Chlorin (Cl)	8.2671	Chlorin (Cl)	8.2671
Sulfuric acid ion (SO_4)	.0034	Sulfuric anhydrid (SO_3)	.0026
Silicic acid ion (SiO_3)	.0111	Silicic anhydrid (SiO_2)	.0088
		Carbonic anhydrid (CO_2)	.9082
		Water (H_2O)	.1867
		Oxygen equivalent	1.8660
		Total	15.2711

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	13.6630	798.0558
Sodium bicarbonate ($NaHCO_3$)	.0242	1.4135
Calcium sulfate ($CaSO_4$)	.0040	.2336
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.9500	55.4895
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.6060	35.3964
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0151	.8819
Silica (SiO_2)	.0088	.5140
Totals	15.2711	891.9847
Carbon-dioxid gas	abundant.	

Analysis by E. H. S. Bailey and F. B. Porter.

Paola, Miami County.

On the farm of Joe Schafges, four miles southeast of Paola, is a bored well ninety feet deep. This does not yield natural gas. The water gives upon evaporation 406 grains of solid matter per gallon. Of this, 292 grains is common salt. The rest of the material is calcium and magnesium carbonates, with probably considerable sodium carbonate. This water is recommended as of excellent medicinal quality by local physicians.

Piqua Brine Well, Woodson County.

This well is situated on a farm one mile west and three-fourths of a mile north of Piqua. It is 171 feet deep, and the water rises to within seventy feet of the surface. When the well was drilled for a time considerable gas escaped with the water. As this drilling was done in 1883, before the Iola gas field was known, the presence of oil and gas with the brine at this locality created considerable excitement. This is about eight miles from the Iola gas field. The water has the following composition:

PIQUA WELL.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	4.5403	Sodium oxid (Na_2O)	6.1194
Potassium (K)	.1699	Potassium oxid (K_2O)	.2049
Calcium (Ca)	.1730	Calcium oxid (CaO)	.2414
Magnesium (Mg)	.1086	Magnesium oxid (MgO)	.1812
Iron (Fe)	trace	Iron oxid (FeO)	trace
Chlorin (Cl)	7.1270	Chlorin (Cl)	7.1270
Sulfuric acid ion (SO_4)	.0824	Sulfuric anhydrid (SO_3)	.0686
Silicic acid ion (SiO_3)	trace	Silicic anhydrid (SiO_2)	trace
		Carbonic anhydrid (CO_2)	.7222
		Water (H_2O)	.1477
		Oxygen equivalent	1.6105
		Total	13.2019

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	11.5026	671.8668
Sodium bicarbonate ($NaHCO_3$)	.0368	2.1494
Potassium chlorid (KCl)	.3242	18.9365
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.6985	40.7993
Magnesium sulfate ($MgSO_4$)	.1029	6.0103
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.5369	31.3603
Iron bicarbonate ($FeH_2(CO_3)_2$)	trace	trace
Silica (SiO_2)	trace	trace
Totals	13.2019	771.1226

Specific gravity 1.01

Analysis by E. H. S. Bailey.

Wyandotte Gas Well.

In 1885 a well was bored at Wyandotte (now Kansas City), Kan., with a hope of finding oil or gas. Some oil and gas were obtained, and for several years the gas was used as fuel for a planing-mill near by. The oil has also been examined.[72] The water from this well does not contain as much salt as the bromo-magnesium well at Independence, still it is a strong brine. The depth of the well is 350 feet.

WYANDOTTE WELL.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	10.127	Sodium oxid (Na_2O)	13.651
Calcium (Ca)	.707	Calcium oxid (CaO)	.562
Magnesium (Mg)	.244	Magnesium oxid (MgO)	.407
Iron (Fe)	.008	Iron oxid (FeO)	.011
Chlorin (Cl)	16.254	Chlorin (Cl)	16.254
Sulfuric acid ion (SO_4)	.006	Sulfuric anhydrid (SO_3)	.005
Silicic acid ion (SiO_3)	.012	Silica (SiO_2)	.010
		Organic matter	.210
		Carbonic anhydrid (CO_2)	1.036
		Water (H_2O)	.212
		Oxygen equivalent	3.585
		Total	28.700

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	25.761	1504.758
Calcium chlorid ($CaCl_2$)	.962	56.190
Calcium sulfate ($CaSO_4$)	.009	.525
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.236	13.780
Magnesium carbonate ($MgH_2(CO_3)_2$)	1.485	86.738
Iron bicarbonate ($FeH_2(CO_3)_2$)	.027	1.577
Silica (SiO_2)	.010	.584
Organic matter by difference	.210	12.225
Totals	28.700	1676.377

Analysis by E. C. Franklin.

This water also contained traces of bromin and potassium.

72. Quarterly Report Kansas State Board of Agriculture, December 31, 1885.

COMPARISON OF SIMILAR WATERS.

The chlor-carbonate group is well represented by many famous waters both in this country and abroad. Some contain only small quantities of mineral matter, while others are heavily mineralized. On account of the abundance of free carbon dioxid which they contain, they are usually clear, sparkling, effervescent, and agreeable to the taste, especially at a comparatively low temperature. Some typical waters are:

Putah, Lake County, Cal., Howard Springs, Excelsior Spring.

Grains per gallon.

Analysis by W. T. Wenzell.

Sodium chlorid	101.67	Iron bicarbonate	1.85
Sodium bicarbonate	34.10	Alumina	.03
Potassium chlorid	1.13	Silica	13.10
Lithium chlorid	8.35	Organic matter	.14
Calcium bicarbonate	6.30	Total	169.48
Magnesium bicarbonate	2.81		

Free carbon dioxid.............. 134 cubic inches.

Saratoga, N. Y., Hathorn Spring.

Analysis by C. F. Chandler.

Sodium chlorid	509.968	Calcium bicarbonate	170.646
Sodium bromid	1.534	Magnesium bicarbonate	176.463
Sodium iodid	.198	Barium bicarbonate	1.737
Sodium phosphate	.006	Ferrous bicarbonate	1.128
Sodium bicarbonate	4.288	Alumina	.131
Potassium chlorid	9.597	Silica	1.260
Lithium bicarbonate	11.447	Total	888.403

Carbon dioxid............... 575.747 cubic inches.

Ems on the Lahn, Germany, Kesselbrunnen.

Analysis by Fresenius.

Sodium chlorid	62.164	Ferrous carbonate	.162
Sodium carbonate	80.303	Manganese carbonate	.028
Sodium sulfate	.049	Aluminum phosphate	.077
Potassium sulfate	3.149	Silica	2.918
Calcium carbonate	10.073	Total	165.755
Magnesium carbonate	6.808		
Strontium and barium carbonates	.024		

Carbon dioxid............ 54.304 cubic inches.

Nassau, Germany, Selters (Seltzer).

Analysis by Hastner.

Sodium chlorid	137.824
Sodium carbonate	54.224
Sodium sulfate	2.088
Sodium phosphate	.002
Potassium chlorid	2.312
Calcium sulfate	2.088
Calcium carbonate	14.816
Calcium fluorid	.013
Magnesium carbonate	12.128
Manganese carbonate	.016
Ferrous carbonate	.632
Aluminum phosphate	.003
Silica	2.000
Total	228.148

A Comparison of some of the Most Important Constituents of the *Chlor-Carbonate* Group.

Grains per gallon.

NAME.	Solids.	Sodium chlorid.	Sodium bicarbonate.	Calcium bicarbonate.	Magnesium bicarbonate.
Cherryvale	111	51	52	2	4
Iola	1100	971	8	60	25
Miller	891	798	1	55	35
Piqua	771	671	2	40	31
Wyandotte	1676	1504	....	13	86
Fort Scott	109	79	....	14	trace
Putah, Cal	169	101	34	6	3
Hathorn, Saratoga	888	509	4	170	176
Ems, Germany	165	*62	*80	10	6
Nassau, Germany	228	*137	*54	*14	*12

*Carbonate.

As in the previous group, here, also, the sodium carbonate is small, and the free carbon dioxid is not abundant. On this account it is not easy to find waters that are similar to the Kansas waters. The Kansas waters contain common salt, with calcium and magnesium bicarbonates, while waters like Hathorn contain the same ingredients, but the water is surcharged with carbon-dioxid gas.

CHAPTER XV.

The Sulfid Group.

Sulfid waters, or those giving off free hydrogen-sulfid gas, are very widely distributed all over the world. This gas, which is considered of great value by many physicians as a constituent of mineral waters, often issues from the earth in the vicinity of semi-active volcanoes, and the chemist readily understands how it may be set free by the action of hot water on sulfids. Organic matter, which has a tendency to reduce sulfates to sulfids, often assists very much in its formation. The therapeutic action of this gas has already been discussed (see pp. 65–67).

These waters may contain not only the free hydrogen-sulfid gas, but the sulfids, sulfhydrates, and perhaps thiosulfates (hyposulfites). The therapeutic action, as has been noticed, is supposed to be different when we have a solution of a sulfid, etc., from the action of the gas simply dissolved in water.

The sulfur waters of Kansas are not numerous, but some of them may become of importance. Several of these waters are those that supply the cities of the southeastern part of the state. Here the surface-waters are very unsatisfactory on account of the proximity of coal-mines, and the deep well-waters are the only supply available. As the deep-well waters are allowed to stand exposed to the air oxidation takes place, and a white deposit of sulfur soon forms in the reservoir. If the water is delivered to customers directly, without proper aeration, the smell of hydrogen sulfid still remains in it, but the residents, at least, soon become accustomed to this taste, and, as otherwise the amount of mineral matter is not large, the water is favorably regarded. There is, however, a possibility in the extreme southeast that these deep wells may strike veins of lead and zinc, and that the water may be contaminated with these metals, especially the latter.

Other waters here classified are rich in chlorids, and would be classified as dilute brines, if they did not contain hydrogen-sulfid gas. They possess, therefore, the therapeutic properties of both classes of waters.

A sulfur water can be recognized not only by the odor, which is that of rotten eggs, but also by the deposit of yellowish-white matter (sulfur) in the spring. In some waters there is a black deposit of iron sulfid. A silver coin placed in the water soon becomes black from the formation of silver sulfid on the surface.

This group is represented by the following waters:

Brookville, Saline county.
Cherokee, Cherokee county.
Columbus, Cherokee county.
Sulfur Well, Cloud county.
Fort Scott, Bourbon county, artesian well.
Fort Scott sulfo-magnesian well.
Girard, Crawford county.
Haddon mineral well, Geary county.
Madison, Sulfur Well, Greenwood county,.
Pittsburg, Crawford county.
Wakefield, Sulfur Well, Clay county.

Brookville Well, Saline County.

The water from a well some distance southwest of Brookville proves to be a strong sulfur water. It is clear and limpid at first, but after a time deposits a sediment. The water contains much magnesia and iron, probably existing as chlorids; calcium, as sulfate and sulfid; sodium chlorid, silica, and free hydrogen-sulfid gas. This water may be mentioned as of considerable interest, and quite likely to be of value medicinally.

The Cherokee Well.

In the southeastern part of the state it was for some years difficult to obtain good water for domestic purposes. Shallow wells in the vicinity of the coal deposits yielded water that was very unsatisfactory, and the surface-waters were liable to be contaminated with the drainage from the mines. On this ac-

count deep wells have been bored in several localities, especially for a public supply in the cities of Cherokee, Columbus, Girard, Pittsburg, Weir City, Fleming, and Midland. Though some of the waters are not so good as might be desired, they are more wholesome than that from surface wells.

The well at Cherokee is just south of the city, and the plant may be taken as a type for the others. This well is 916 feet deep, with 315 feet cased. The upper part of the well is cased with eight-inch tubing, and the lower part with six-inch tubing. This casing is cemented to the rock to keep out all waters flowing over the coal strata. No less than 30,000 gallons per day are pumped from this well without exhausting the supply. As will be noticed in the case of the other wells of this character, the temperature of the water is somewhat high. The white deposit of sulfur separates out of the water after it has stood some time, and the water when first drawn has the odor of hydrogen sulfid. The Cherokee plant was constructed in 1896, and is owned by the city.

CHEROKEE CITY WELL.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.1310	Sodium oxid (Na_2O)	.1769
Potassium (K)	.0085	Potassium oxid (K_2O)	.0103
Calcium (Ca)	.0622	Calcium oxid (CaO)	.0869
Magnesium (Mg)	.0313	Magnesium oxid (MgO)	.0521
Aluminum (Al)	.0019	Aluminum oxid (Al_2O_3)	.0037
Chlorin (Cl)	.0943	Chlorin (Cl)	.0943
Sulfuric acid ion (SO_4)	.1423	Sulfuric anhydrid (SO_3)	.1187
Silicic acid ion (SiO_3)	.0112	Silicic anhydrid (SiO_2)	.0089
		Carbonic anhydrid (CO_2)	.2478
		Water (H_2O)	.0538
		Oxygen equivalent	.0212
		Total	.8322

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid ($NaCl$)	.1551	9.045
Sodium bicarbonate ($NaHCO_3$)	.1838	10.719
Sodium sulfate (Na_2SO_4)	.0497	2.898
Potassium sulfate (K_2SO_4)	.0190	1.108
Calcium sulfate ($CaSO_4$)	.1541	8.988
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.0678	3.954
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.1901	11.086
Alumina (Al_2O_3)	.0037	.216
Silica (SiO_2)	.0089	.519
Totals	.8322	48.543
Hydrogen-sulfid gas	abundant.	
Temperature	22° C. (71.5° F.)	

Analysis by E. H. S. Bailey and A. S. Hull.

Cloud County Sulphur Spring.[73]

IONS.	Grams per liter.
Sodium (Na)	trace
Calcium (Ca)	.1171
Magnesium (Mg)	.0065
Iron (Fe)	trace
Sulfuric acid ion (SO_4)	.1432

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium sulfate (Na_2SO_4)	trace	trace
Calcium sulfate ($CaSO_4$)	.1662	9.698
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.2753	16.064
Magnesium sulfate ($MgSO_4$)	.0325	1.922
Iron bicarbonate ($FeH_2(CO_3)_2$)	trace	trace
Hydrogen sulfid (H_2S)	.3157	18.443
Totals	.7897	46.127

Analysis by G. H. Failyer.

Columbus Well.

The well in Columbus is still deeper than that at Cherokee, being 1400 feet deep. A well ninety feet deep and ten feet in diameter is pierced at the bottom by a four-inch hole, which is cased to the bottom. The pump, which is of the ordinary lifting variety, is placed at a depth of sixty-five feet in the well, but the water is usually about on a level with the pump. After

73. Bull. U. S. Geol. Surv. No. 32, p. 174.

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73. Bull. U. S. Geol. Surv. No. 32, p. 174.

lifting the water to the surface, it is discharged through an aerating fountain into the center of a basin or reservoir. From this it is pumped to a stand-tower some distance away. While standing in the reservoir it has been noticed that the sulfur separates from the water and gives it a milky appearance, which is said by the local observers to be more marked before a storm. The odor and taste of hydrogen sulfid are both very apparent in the freshly-drawn water.

COLUMBUS WELL.[74]

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.1150	Sodium oxid (Na_2O)	.1551
Potassium (K)	.0034	Potassium oxid (K_2O)	.0042
Lithium (Li)	.0001	Lithium oxid (Li_2O)	.0001
Calcium (Ca)	.0433	Calcium oxid (CaO)	.0607
Magnesim (Mg)	.0221	Magnesium oxid (MgO)	.0368
Strontium (Sr)	trace	Strontium oxid (SrO)	trace
Iron (Fe)	.0004	Iron oxid (FeO)	.0007
Aluminum (Al)	trace	Aluminum oxid (Al_2O_3)	trace
Manganese (Mn)	.0002	Manganese oxid (MnO)	.0003
Chlorin (Cl)	.0355	Chlorin (Cl)	.0355
Sulfuric acid ion (SO_4)	.0144	Sulfuric anhydrid (SO_3)	.0120
Thiosulfuric acid ion (S_2O_3)	.0084	Thiosulfuric anhydrid (S_2O_2)	.0072
Silicic acid ion (SiO_3)	.0085	Silicic anhydrid (SiO_2)	.0067
		Carbonic anhydrid	not determined
		Hydrogen sulfid (H_2S)	.0110

Hydrogen sulfid.......... 7.27 cc. per liter, or 1.68 cu. in. per gal.
Temperature............. 24° C. (75.2° F.)

Analysis by G. H. Failyer and J. T. Willard.

Fort Scott Artesian Well.[75]

As early as 1884 a well was bored at Fort Scott for the purpose of obtaining gas. The mouth of this well is 840 feet above the level of the sea, as shown by the survey of the Kansas City, Fort Scott & Memphis Railway Company. It is bored on the south branch of Marmaton river, at the foot of a bluff 550 feet from the channel. The mouth of the well is 100 feet lower than the plateau. The bluff appears to consist of limestone, hydraulic cement, coal, fire-clay, and bituminous shales. The diameter of the well is eight inches

74. Proc. Kan. Acad. Sci., vol. X, p. 64.

75. Kansas City Review of Science and Industry, vol. VIII, p. 485. Also, Trans. Kan. Acad. Sci., vol. IX, pp. 96, 97.

down to 335 feet, to which point the well was tubed with iron pipe to keep out the surface-water. Below that point the well was bored dry forty-five feet to a depth of 380 feet, at which point the drill struck fourteen inches of gravel, and salt water rose to within eighteen feet of the surface. Boring was then continued to a depth of 510 feet, when water of a different composition was found, which began to flow slowly from the well. At a depth of 621 feet the boring was discontinued and the drill removed.

Since that time the well has flowed a clear, steady stream, said to be over 10,000 gallons per day. The flow is practically continuous, without any gaseous agitation. The pressure of the water is sufficient to raise it in a pipe five feet above the mouth of the well, at which height it remains stationary. For the drill record of the well the author is indebted to Mr. E. F. Ware, at that time secretary of the artesian well company that made the original boring. The drilling record, which is an interesting one, is as follows:

		Total.
Wash dirt	25 feet.	25 feet.
Clay	5 "	30 "
Soapstone	15 "	45 "
Slate	3 "	48 "
Coal	2 inches.	....
Soapstone	15 feet.	63 feet.
Slate	2 "	65 "
Coal	2 inches.	....
Soapstone	17 feet.	82 feet.
Blue limestone	3 "	85 "
Soapstone	95 "	180 "
Soft sandstone	5 "	185 "
Soapstone	70 "	253 "
Brown sandstone	25 "	280 "
Gray sandstone	7 "	287 "
White sandstone	25 "	312 "
Slate	12 "	324 "
Fire-clay	4 "	328 "
Soapstone and slate	10 "	338 "
Slate and iron pyrites	5 "	343 "
Flint	23 "	366 "
Flint and limestone	14 "	380 "
Crevice	14 inches.	381 "
Limestone	4 feet.	385 feet.
Lime and flint	75 "	460 "
Very hard flint	5 "	465 "
Mixed flint and limestone	156 "	621 "

For the last 250 feet the borings were white mixed with gray, the pieces showing frequent specks of iron rust.

The water, which has a slightly sulfurous odor, rises smoothly and steadily in a six-inch tube. This water, as may be seen from the analysis below, may be classed as sulfo-saline, containing borax and lithium as rare ingredients. Comparing this water with that of other wells, we find it to be similar to that of the Blue Lick Spring, of Kentucky, except that the Fort Scott water is more dilute and contains borax as an additional ingredient. As stated above, it is quite probable that the water as analyzed is a mixture of waters from different depths. Fort Scott is easily reached by either the Missouri Pacific, the St. Louis & San Francisco or the Missouri, Kansas & Texas railroads. The composition of the water is as follows:

Fort Scott Artesian Well.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.5499	Sodium oxid (Na_2O)	.7348
Potassium (K)	trace	Potassium oxid (K_2O)	trace
Lithium (Li)	trace	Lithium oxid (Li_2O)	trace
Calcium (Ca)	.0695	Calcium oxid (CaO)	.0973
Magnesium (Mg)	.0354	Magnesium oxid (MgO)	.0591
Iron (Fe)	.0054	Iron oxid (FeO)	.0070
Chlorin (Cl)	.9366	Chlorin (Cl)	.9366
Sulfuric acid ion (SO_4)	.0100	Sulfuric anhydrid (SO_3)	.0083
Boric acid ion (B_4O_7)	.0292	Boric anhydrid (B_4O_6)	.0262
Silicic acid ion (SiO_3)	.0206	Silicic anhydrid (SiO_2)	.0163
		Organic matter	.0201
		Carbonic anhydrid (CO_2)	.1442
		Water (H_2O)	.0296
		Sodium hydrosulfid (NaHS)	.0032
		Oxygen equivalent	.2114
		Total	1.8713

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	1.3627	79.597
Sodium biborate ($Na_2B_4O_7$)	.0378	2.208
Sodium sulfate (Na_2SO_4)	trace	trace
Sodium hydrosulfid (NaHS)	.0032	.188
Potassium chlorid (KCl)	trace	trace
Lithium chlorid (LiCl)	trace	trace
Calcium chlorid ($CaCl_2$)	.0135	.788
Calcium sulfate ($CaSO_4$)	.0142	.830
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.2442	14.260
Magnesium chlorid ($MgCl_2$)	.1368	7.999
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.0052	.306
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0173	1.008
Silica (SiO_2)	.0163	.952
Organic matter	.0201	1.169
Totals	1.8713	109.305

Free hydrogen sulfid	trace.
Free carbon dioxid	trace.
Temperature	19.7° C. (67.5° F.)

Analysis by E. H. S. Bailey and E. W. Walter.

Fort Scott Sulfo-magnesian Well.

A well 700 feet deep has been bored a short distance south of the Goodlander hotel, in the city of Fort Scott, and in this well the water rises to within forty feet of the surface. The upper part of the well is cased with eight-inch pipe and the lower part with six inch. The water, which is nearly clear when freshly drawn, is delivered by a steam pump at the rate of twenty gallons per minute. After the water stands for a while a black sediment settles out. This consists essentially of iron hydroxid and sulfid. The odor and taste of hydrogen sulfid are very strong in the freshly-drawn water. The water is extensively used locally, and it is proposed to utilize it in a sanitarium to be built on the lot adjoining the well.

At present the water is used in a temporary sanitarium which has been fitted up in the basement of the Goodlander hotel. Here are the usual facilities for taking mineral baths.

The Goodlander sanitarium has been recently leased by F. C. Oehler, and has been put in charge of T. L. Bishop, a hydropathist.

The most important characteristics of this water are the hydrogen sufid, the amount of which compares favorably with other sulfur wells and springs; the common salt, which, however, is not present in such an excess as to render the water disagreeable to the taste; the magnesium salts, which have a cathartic action; the presence of a small quantity of borax; and, finally, the alkaline quality of the water, on account of the presence of sodium bicarbonate.

The Goodlander Hotel and Sanitarium, Fort Scott, Kan.

FORT SCOTT SULFO-MAGNESIAN WELL.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.5945	Sodium oxid (Na_2O)	.8198
Potassium (K)	.0100	Potassium oxid (K_2O)	.0122
Calcium (Ca)	.0763	Calcium oxid (CaO)	.1023
Magnesium (Mg)	.0357	Magnesium oxid (MgO)	.0595
Iron (Fe)	.0021	Iron oxid (FeO)	.0027
Aluminum (Al)	.0076	Aluminum oxid (Al_2O_3)	.0144
Chlorin (Cl)	.9441	Chlorin (Cl)	.9399
Sulfuric acid ion (SO_4)	.0062	Sulfuric anhydrid (SO_3)	.0052
Boric acid ion (B_4O_7)	.0110	Boric anhydrid (B_4O_6)	.0102
Silicic acid ion (SiO_3)	.0258	Silica (SiO_2)	.0204
Sulfur (S)	.0203	Carbonic anhydrid (CO_2)	.2908
		Water (H_2O)	.0591
		Oxygen equivalent	.2120
		Total	2.1244

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium biborate ($Na_2B_4O_7$)	.0147	.8586
Sodium bicarbonate ($NaHCO_3$)	.2620	15.3034
Sodium sulfid (NaHS)	trace	trace
Sodium chlorid (NaCl)	1.3536	79.0767
Potassium sulfate (K_2SO_4)	.0113	.6600
Potassium chlorid (KCl)	.0096	.5607
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.2768	16.1678
Calcium chlorid ($CaCl_2$)	.0140	.8177
Magnesium chlorid ($MgCl_2$)	.1410	8.2358
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0066	.4497
Aluminum oxid (Al_2O_3)	.0144	.8411
Silica (SiO_2)	.0204	1.1916
Sulfur (S)	trace	trace
Totals	2.1244	124.1631
Temperature	19.5° C. (67° F.)	

Analysis by E. H. S. Bailey.

Girard Well.

The depth of this well is 980 feet, and from it 3526 gallons per hour are pumped. The water is 175 feet below the surface, so a pump rod extending to a depth of over 200 feet is used. The casing of the well extends down for 200 feet and the water is lifted directly into a tank above the pump-house. In most places this plan of lifting the water directly to the distributing reservoir has not been found so satisfactory as the plan of allowing the water to stand in a storage reservoir for a time, in order to aerate and give off its hydrogen-sulfid gas. The analysis of the water of this well is as follows:

GIRARD WELL.[76]

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.2686	Sodium oxid (Na_2O)	.3958
Calcium (Ca)	.0932	Calcium oxid (CaO)	.1255
Magnesium (Mg)	.0342	Magnesium oxid (MgO)	.0570
Iron (Fe)	.0009	Iron oxid (FeO)	.0022
Chlorin (Cl)	.4025	Chlorin (Cl)	.4025
Sulfuric acid ion (SO_4)	.3681	Sulfuric anhydrid (SO_3)	.3068
Silicic acid ion (SiO_3)	.0221	Silicic anhydrid (SiO_2)	.0175
Carbonic acid ion (CO_3)	.0081	Carbonic anhydrid (CO_2)	.0510
		Water (H_2O)	.0104
		Oxygen equivalent	.0910
		Total	1.2777

76. Trans. Kan. Acad. Sci., vol. XV, pp. 85, 86.

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.6632	38.7375
Sodium sulfate (Na_2SO_4)	.0824	4.8130
Sodium bicarbonate ($NaHCO_3$)	.0226	1.3201
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.0668	3.9018
Calcium sulfate ($CaSO_4$)	.2486	14.5207
Magnesium sulfate ($MgSO_4$)	.1711	9.9939
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0055	.3212
Silica (SiO_2)	.0175	1.0222
Totals	1.2777	74.6304

Temperature .... 23.8° C. (75° F.)

Analysis by E. H. S. Bailey and H. E. Davies.

Moss Springs Well, Geary County.

A well drilled in 1883 at Moss Springs, on the property formerly owned by Mr. Haddon, in the southeastern part of Geary county, was reported by Professor Failyer. "The well is eighty feet deep. The owner of the well states that at a depth of about sixty feet a blowing noise was heard in the well, as though a cavity containing compressed gas had been tapped. He does not remember to have observed the odor of hydrogen-sulfid gas at this time. The noise may have been due to the escape of this gas, but it does not seem probable." The well is now owned by R. A. Snedaker, Alta Vista P. O.

MOSS SPRINGS WELL.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.5317	Sodium oxid (Na_2O)	.7155
Lithium (Li)	trace	Lithium oxid Li_2O)	trace
Calcium (Ca)	.2008	Calcium oxid (CaO)	.2812
Magnesium (Mg)	.1041	Magnesium oxid (MgO)	.1739
Iron (Fe)	.0025	Iron oxid (FeO)	.0033
Aluminum (Al)	.0128	Aluminum oxid (Al_2O_3)	.0241
Chlorin (Cl)	.0137	Chlorin (Cl)	.0137
Iodin (I)	trace	Iodin (I)	trace
Sulfuric acid ion (SO_4)	.7710	Sulfuric anhydrid (SO_3)	.6412
Phosphoric acid ion (PO_4)	trace	Phosphoric anhydrid (P_2O_5)	trace
Boric acid ion (B_4O_7)	trace	Boric anhydrid (B_4O_6)	trace
Silicic acid ion (SiO_3)	.0107	Silicic anhydrid (SiO_2)	.0150
		Carbonic anhydrid (CO_2)	.0188
		Hydrogen sulfid (H_2S)	.0337

Analysis by G. H. Failyer.

Sulfur Well, Greenwood County.

This is about eleven miles northwest of Madison. The sulfur is said to deposit from the water when it is allowed to stand.

In the vicinity of Madison, and also in Lyon county, in the valley of the Verdigris, there are a number of wells containing saline waters.

SULFUR WELL, MADISON.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	1.3604	Sodium oxid (Na_2O)	1.8391
Calcium (Ca)	.1661	Calcium oxid (CaO)	.2329
Magnesium (Mg)	.0016	Magnesium oxid (MgO)	.0027
Iron and aluminum (Fe and Al),	trace	Iron and aluminum oxids (Fe_2O_3 and Al_2O_3)	trace
Sulfuric acid ion (SO_4)	.5442	Sulfuric anhydrid (SO_3)	.4525
Chlorin (Cl)	1.9163	Chlorin (Cl)	1.9163
Silicic acid ion (SiO_3)	.0236	Silica and insol. residue (SiO_2),	.0186
		Carbon dioxid (CO_2)	considerable
		Carbon dioxid combined	.1063
		Water (H_2O)	.0143
		Oxygen equivalent	.4336
		Total	4.1491

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	3.1625	184.7216
Sodium sulfate (Na_2SO_4)	.3648	21.3079
Calcium sulfate ($CaSO_4$)	.4199	24.5693
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.1735	10.1202
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.0098	.5435
Silica and insoluble residue	.0186	1.0864
Totals	4.1491	242.3489

Analysis by F. W. Bushong.

Pittsburg Well.

The well supplying the city of Pittsburg with water is not far from the main street and near the principal hotel, in the northern part of the town. There is a reservoir 130 feet below the surface into which the well discharges, and from this the water is pumped to an aerating basin on the surface. The water is allowed to stand here for some time and then it is pumped to an elevated tank, from which it is distributed. The temperature of the water is 18.3° C. (65° F.) A partial analysis of this water shows it to contain about the same constituents as the other deep wells in this section of the state. There is the usual amount of hydrogen sulfid, which causes a deposit of sulfur in the reservoir when the water is allowed to stand for some time.

Wakefield Sulfur Well.

This well is situated on the farm of Dr. Charles Hewitt, on the south side of a bluff which is 100 feet above the bed of the Republican river, at a point in Clay county where the river runs toward the east. The well is 122 feet deep, and ordinarily contains forty feet of water, which can be lowered to twelve feet by vigorous pumping. The well is drilled through rock for at least two-thirds of its depth, and there is a very flinty rock at the bottom. It furnishes an abundance of water from a strong vein, so that an ordinary windmill will supply a continuous stream. The location of the well would indicate a depth of about eighty feet below the river bed.

The water when first drawn has quite a milky appearance, and emits an odor of hydrogen sulfid. It becomes perfectly clear on standing and deposits a small quantity of white sediment. If the water is allowed to stand for several weeks, in a closed vessel, it deposits a black precipitate, which is no doubt iron sulfid, and there is a considerable odor of hydrogen sulfid. Sometimes, however, there is no odor of hydrogen sulfid to be noticed from the freshly-drawn water. This may be on account of its alkaline character. As the analysis shows the presence of large quantities of sulfates, it is evident that something in the water has a reducing action,

which results in the production of hydrogen sulfid. This action then takes place to some extent in the rock strata from which the water comes, but more readily at a higher temperature in a closed vessel, after being drawn.

WAKEFIELD SULFUR WELL.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.1667	Sodium oxid (Na_2O)	.2240
Calcium (Ca)	.3893	Calcium oxid (CaO)	.5449
Magnesium (Mg)	.1050	Magnesium oxid (MgO)	.1743
Iron (Fe)	.0252	Iron oxid (FeO)	.0325
Aluminum (Al)	.0281	Aluminum oxid (Al_2O_3)	.0530
Chlorin (Cl)	.0382	Chlorin (Cl)	.0382
Sulfuric acid ion (SO_4)	.7200	Sulfuric anhydrid (SO_3)	.6002
Silicic acid ion (SiO_3)	.8271	Silicic anhydrid (SiO_2)	.6546
		Carbonic anhydrid (CO_2)	.8881
		Water (H_2O)	.1814
		Oxygen equivalent	.0086
		Total	3.3826

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0630	3.680
Sodium sulfate (Na_2SO_4)	.4364	25.490
Calcium sulfate ($CaSO_4$)	.6034	35.244
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.8582	50.127
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.6336	37.010
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0804	4.695
Aluminum oxid (Al_2O_3)	.0530	3.096
Silica and insoluble residue (SiO_2)	.6546	38.240
Totals	3.3826	197.582

Free hydrogen-sulfid gas.

Analysis by E. H. S. Bailey and B. F. Porter.

COMPARISON OF SIMILAR WATERS.

Grains per gallon.

Greenbrier, White Sulfur Springs, Virginia.

Analysis by A. A. Hayes.

This is one of the most-noted sulfur springs in the world.

Calcium carbonate	7.07	Silicates	3.46
Calcium sulfate	78.35	Organic matter	4.36
Magnesium chlorid	1.00	Total	129.66
Magnesium sulfate	35.42		

Carbon-dioxid gas	11.28 cubic inches.
Hydrogen-sulfid gas	.24 "
Oxygen	.48 "
Nitrogen	4.64 "

Temperature, 62° F. Flow, 1800 gallons per hour.

Colusa County, California, Wilbur Springs.

Analysis by Winslow Anderson.

Sodium chlorid	19.75	Magnesium carbonate	5.10
Sodium carbonate	3.40	Magnesium sulfate	22.90
Sodium sulfate	26.19	Ferrous sulfate	4.16
Potassium chlorid	.46	Alumina	3.93
Potassium iodid	.75	Silicates	6.95
Calcium carbonate	8.44	Organic matter	1.74
Calcium sulfate	20.62	Total	124.39

Hydrogen-sulfid gas............... 43.97 cubic inches.

Alpena, Mich., Alpena Magnetic Well.

Analysis by Professor Edwards.

Sodium chlorid	243.89	Calcium sulfid	182.56
Sodium carbonate	1.67	Magnesium chlorid	78.22
Sodium sulfid	28.05	Total	534.39

Hydrogen-sulfid gas...... 7.38 cubic inches.

Sharon Springs, N. Y., White Sulfur Spring.

Analysis by Lawrence Reid.

Sodium chlorid, Magnesium chlorid	2.70	Calcium sulfate	85.40
		Magnesium bicarbonate	24.00
Calcium sulfid, Magnesium sulfid	3.00	Magnesium sulfate	34.00
		Total	149.10

Hydrogen-sulfid gas............... 20.50 cubic inches.

Sandwich Springs, Ontario, Canada.

Analysis by S. P. Duffield.

Sodium chlorid	.560	Magnesium chlorid	153.760
Sodium carbonate	48.560	Magnesium carbonate	12.944
Calcium chlorid	.056	Silica	.112
Calcium carbonate	38.504	Total	378.328
Calcium sulfate	123.832		

Carbon-dioxid gas	10.00 cubic inches.
Hydrogen-sulfid gas	37.76 "
Nitrogen gas	.72 "

Aix-les-Bains, France, Sulfur Spring.

Analysis by Bonjeau.

Sodium chlorid	.466	Magnesium chlorid	1.000
Sodium sulfate	5.608	Magnesium carbonate	1.504
Calcium carbonate	8.672	Magnesium sulfate	2.056
Calcium sulfate	.936	Ferrous carbonate	.512
Calcium phosphate, Calcium fluorid, Aluminum phosphate	.136	Aluminum sulfate	3.200
		Silica	.288
		Loss	.696
		Total	25.074

Carbon-dioxid gas	3.12 cubic inches.
Hydrogen-sulfid gas	6.56 "
Nitrogen	152.32 "
Temperature	108–110° F.

Nenndorf, Hesse, Germany, Trinkquelle.

Analysis by Bunsen.

Sodium sulfate	36.392	Magnesium chlorid	14.808
Potassium sulfate	2.712	Magnesium sulfate	18.544
Calcium carbonate	27.048	Silica	1.296
Calcium sulfate	64.968	Total	170.208
Calcium sulfid	4.440		

	Cubic inches.
Carbon-dioxid gas	42.00
Hydrogen-sulfid gas	10.64
Carbureted hydrogen	.40
Nitrogen	4.88

Harrowgate, England, Old Sulfur Well.

Analysis by A. W. Hoffman.

Sodium chlorid	688.144	Calcium fluorid	trace
Sodium iodid	trace	Magnesium chlorid	44.552
Sodium bromid	trace	Ferrous carbonate	trace
Sodium sulfid	12.384	Manganese carbonate	trace
Potassium chlorid	43.760	Ammonia	trace
Calcium chlorid	65.392	Silica	.200
Calcium carbonate	9.896	Total	864.432
Calcium sulfate	.104		

Gases.	Cubic inches.
Carbon dioxid	17.600
Hydrogen sulfid	4.248
Nitrogen	2.328
Marsh gas	4.672

A Comparison of Some of the Most Important Constituents of the Sulfid Group.

The comparison of these waters shows that there is very little analogy between them. They are simply waters of various classes that contain hydrogen-sulfid gas, hydrosulfids, sulfids, or hyposulfites. The amount of mineral matter varies between wide limits, as the analyses quoted show; that of Aix-les-Bains contains only twenty-five grains per gallon, while the Harrowgate water contains 864 grains. Chlorids are usually found, and sulfates are not wanting in any of the waters discussed. Indeed, sulfates would always be looked for in these waters, as the sulfate ion is produced by the oxidation of the sulfur ion. The only exception to this would be in waters that contained barium and strontium, as does the Geyser well at Rosedale; here the sulfid may have oxidized and precipitated a part of the barium and strontium as sulfates. Magnesium and calcium are also generally present, but the carbonate ion is not usually abundant.

CHAPTER XVI.

Chalybeate (Iron) Group.

The iron waters are usually carbonates, though the iron in some cases is regarded as a sulfate. Many of the waters here mentioned might very properly go in group IV as carbonates.

Where there is only a small quantity of sulfate in the water it is evident that the iron has come from sandstones or similar rocks, and has been reduced by the organic matter which accompanies the water in its course through the underground strata. Much of the soil contains an abundance of iron, and the waters, already charged with carbonic-acid gas holding calcium and magnesium salts in solution as bicarbonates, have only to come in contact with this iron and the rich vegetable mold to become in turn chalybeate waters.

Many shales are filled with crystals of iron pyrites, and these, under the influence of air and moisture, especially in contact with organic matter, will oxidize, forming iron sulfate. Coal itself, or partially formed coal, as peat, is readily disintegrated by the action of the decomposing sulfids. Ordinary soft coal has but to be exposed to "weathering" to fall to pieces from this same cause. This gives us "mine water," or, if shale which contains alumina has also been in contact with the decomposing material, an "alum water" is the result. It is evident that the action of an iron-sulfate water, or an iron-chlorid water—both strong astringents—would be quite different from that of an iron-carbonate water. (See p. 55 for therapeutic action.)

This group is represented by the following waters:

Arrington, Atchison county, Nos. 1, 2, and 3.

Atchison, McDuff's spring.

Atchison, Electric Light Company's well.

Bonner Springs, Leavenworth county, Forest Lake well.
Bonner Springs, Leavenworth county, Forest Lake spring.
Bonner Springs, Leavenworth county, springs Nos. 4, 5, and 6.
Coyville, Wilson county.
Independence, Montgomery county, Parkhurst's spring.
La Cygne, Linn county.
Lawrence, Douglas county, city supply.
Louisville, Pottawatomie county.
Mahaska, Washington county.
Muscotah, Atchison county.
Topeka, Shawnee county, Mineral well.
Topeka, Shawnee county, Capital well.
Wetmore Springs, Nemaha county.

Arrington Springs.

In the extreme southwestern part of Atchison county, in the valley of the Delaware river and quite near this stream, are situated the Arrington springs. The village is on the Leavenworth, Kansas & Western railroad, midway between Holton and Valley Falls. The springs were among the earliest developed in Kansas, for as early as 1881 improvements were made here. There are numerous springs on both sides of the Delaware river, but those that have the most abundant flow are below the bridge that spans the river, and in the vicinity of the mill. The water from one of these springs (that one nearest the bridge) was formerly piped to a bath-house situated on the north side of the bridge.

IMPROVEMENTS.

The entire property consists of forty acres, but, on account of litigation, no improvements of any importance have been made since the earlier developments. The controlling interest in the springs was about three years ago purchased by D. S. Hencks. On the left bank of the river is a very pretty grove, in which the springs are situated. On the east side of this grove are twelve cottages. A bath-house and engine-house with steam-pump were formerly operated in connection with the springs, but since the burning of the hotel their use has been abandoned. In 1902 a new hotel was built in the village, and the intention is to again develop the springs and make the place a popular resort.

ARRINGTON NO. 1.

IONS.	Grams per liter.
Sodium (Na)	.1183
Potassium (K)	.0144
Lithium (Li)	.0015
Calcium (Ca)	.1165
Magnesium (Mg)	.0374
Iron (Fe)	.0295
Chlorin (Cl)	.0377
Sulfuric acid ion (SO_4)	.0731
Silicic acid ion (SiO_3)	.0210

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0622	3.633
Sodium sulfate (Na_2SO_4)	.0351	2.056
Sodium bicarbonate ($NaHCO_3$)	.3107	18.148
Potassium bicarbonate ($KHCO_3$)	.0355	2.091
Lithium bicarbonate ($LiHCO_3$)	.0148	.864
Calcium sulfate ($CaSO_4$)	.0221	1.291
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.2810	16.413
Magnesium sulfate ($MgSO_4$)	.0321	1.874
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.1766	10.315
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0939	5.484
Silica (SiO_2)	.0169	.987
Ammonium crenate	.0152	.887
Organic matter	.0046	.268
Totals	1.1007	64.311

Temperature........ 13.3° C. (56° F.)

Analysis by Juan H. Wright, M. D.

ARRINGTON NO. 2.

IONS.	Grams per liter.
Sodium (Na)	.0479
Ammonia (NH_4)	trace
Calcium (Ca)	.0454
Magnesium (Mg)	.0156
Iron (Fe)	.0161
Chlorin (Cl)	.0224
Silicic acid ion (SiO_3)	.0204

Cottages, Arrington Springs.

Bath-house and Pavilion, Arrington Springs.

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid ($NaCl$)	.0370	2.164
Sodium bicarbonate ($NaHCO_3$)	.0965	5.637
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.1834	10.728
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.0953	5.569
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0528	3.084
Silica (SiO_2)	.0095	.555
Organic matter	.0161	.911
Ammonia	trace	trace
Totals	.4906	28.648

Analysis by Juan H. Wright, M. D.

ARRINGTON NO. 3.

IONS.	Grams per liter.
Sodium (Na)	.0136
Potassium (K)	trace
Lithium (Li)	trace
Calcium (Ca)	.0240
Magnesium (Mg)	.0622
Iron (Fe)	.0399
Chlorin (Cl)	.0350
Iodin (I)	trace
Sulfuric acid ion (SO_4)	.1802
Silicic acid ion (SiO_3)	.0116

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid ($NaCl$)	.0344	2.003
Potassium iodid (KI)	trace	trace
Lithium (Li)	trace	trace
Calcium sulfate ($CaSO_4$)	.0052	.308
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.0914	5.334
Magnesium chlorid ($MgCl_2$)	.0190	1.112
Magnesium sulfate ($MgSO_4$)	.2205	12.882
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.0611	3.571
Iron bicarbonate ($FeH_2(CO_3)_2$)	.1206	7.044
Silica (SiO_2)	.0092	.541
Totals	.5614	32.795

Analysis by Juan H. Wright, M. D.

Atchison Electric-light Well.

This well is seventy-five feet deep. Iron deposits readily from this water, staining the drinking vessels.

WELL OF THE ATCHISON ELECTRIC-LIGHT AND POWER PLANT.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0414	Sodium oxid (Na_2O)	.0558
Potassium (K)	.0114	Potassium oxid (K_2O)	.0137
Calcium (Ca)	.1141	Calcium oxid (CaO)	.1596
Magnesium (Mg)	.0254	Magnesium oxid (MgO)	.0423
Iron (Fe)	.0675	Iron oxid (FeO)	.0867
Aluminum (Al)	.0300	Aluminum oxid (Al_2O_3)	.0567
Chlorin (Cl)	.0560	Chlorin (Cl)	.0560
Sulfuric acid ion (SO_4)	.0881	Sulfuric anhydrid (SO_3)	.0734
Silicic acid ion (SiO_3)	.0752	Silica (SiO_2)	.0594
		Water (H_2O)	.1098
		Carbonic anhydrid (CO_2)	.5384
		Oxygen equivalent	.0126
		Total	1.2392

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0046	.2687
Sodium bicarbonate ($NaHCO_3$)	.1445	8.4402
Potassium bicarbonate ($KHCO_3$)	.0292	1.7056
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.4617	26.9679
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.1544	9.0185
Iron bicarbonate ($FeH_2(CO_3)_2$)	.2142	12.5114
Aluminum chlorid ($AlCl_3$)	.0666	3.8901
Aluminum sulfate ($Al_2(SO_4)_3$)	.1046	6.1097
Silica (SiO_2)	.0594	3.4695
Totals	1.2392	72.3816

Temperature.......... 13.3° C. (56° F.)

Analysis by E. B. Knerr.

McDuff's Spring, Atchison.

There is a spring on the farm of Mr. Peter McDuff, four and a half miles northwest of Atchison. It is situated on the north side of a ravine, where the general trend of the land is toward the east. The water issues with a pretty strong flow and gives a slight deposit of iron oxid along the course of the stream.

There is no odor of hydrogen sulfid, but a careful chemical test of the freshly-drawn water shows small quantities of this gas. In the vicinity are some very excellent and abundant springs of clear, cold, fresh water. The analysis is as follows:

M'DUFF'S SPRING.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0202	Sodium oxid (Na_2O)	.0272
Potassium (K)	.0168	Potassium oxid (K_2O)	.0202
Calcium (Ca)	.0840	Calcium oxid (CaO)	.1176
Magnesium (Mg)	.0131	Magnesium oxid (MgO)	.0218
Iron (Fe)	.0168	Iron oxid (FeO)	.0216
Aluminum (Al)	.0064	Aluminum oxid (Al_2O_3)	.0120
Chlorin (Cl)	.0240	Chlorin (Cl)	.0240
Sulfur (S)	.0109	Sulfuric anhydrid (SO_3)	.0151
Sulfuric acid ion (SO_4)	.0181	Hydrogen sulfid (H_2S)	.0116
Silicic acid ion (SiO_3)	.0442	Silica (SiO_2)	.0350
		Water (H_2O)	.0615
		Carbonic anhydrid (CO_2)	.3018
		Oxygen equivalent	.0054
		Total	.6640

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0200	1.1666
Sodium bicarbonate ($NaHCO_3$)	.0452	2.6365
Potassium bicarbonate ($KHCO_3$)	.0430	2.5080
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.3401	19.8400
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.0796	4.6430
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0533	3.1090
Aluminum chlorid ($AlCl_3$)	.0148	.8633
Aluminum sulfate ($Al_2(SO_4)_3$)	.0214	1.2430
Silica (SiO_2)	.0350	2.0415
Hydrogen sulfid (H_2S)	.0116	.6766
Totals	.6640	38.7275

Hydrogen-sulfid gas	trace.
Specific gravity	1.00085
Temperature	13.8° C. (57° F.)

Analysis by E. B. Knerr.

Forest Lake, Bonner Springs.

Between Bonner Springs and Edwardsville, on the Union Pacific railway, about two miles below the former station, a small stream runs into the Kaw river from the north. Many years ago a dam was thrown across this stream, thus forming a pond about forty acres in extent, which now has the appearance of a natural lake, as the embankment is overgrown with grass and the banks are well wooded. This lake, known as "Forest Lake," is the property of J. W. McDanield, of Bonner Springs. On the west side the hill is somewhat precipitous and rocky, and from its summit there is a very extensive view to the east and southwest along the valley of the Kaw. The lake is used for harvesting ice in the winter, and, as it is well stocked with fish, it has become a favorite camping and fishing resort.

IMPROVEMENTS.

Pavilions, a dancing platform, a commodious bath-house and landing-place have been erected in the grove on the west side of the lake. There are several wells or springs on the borders of the lake from which the water is drawn by means of ordinary suction-pumps. The water is clear when first drawn, and has a strong taste of iron, and in some cases of hydrogen sulfid. After the water has stood for a short time, like most chalybeate waters, it loses its carbon-dioxid gas and becomes turbid. These waters in this respect do not differ from other iron springs of the Kansas river valley.

FOREST LAKE WELL.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0103	Sodium oxid (Na_2O)	.0139
Calcium (Ca)	.2736	Calcium oxid (CaO)	.3836
Magnesium (Mg)	.0740	Magnesium oxid (MgO)	.1232
Iron (Fe)	.0187	Iron oxid (FeO)	.0241
Chlorin (Cl)	.0159	Chlorin (Cl)	.0159
Sulfuric acid ion (SO_4)	.0600	Sulfuric anhydrid (SO_3)	.0500
Silicic acid ion (SiO_3)	.2095	Silica (SiO_2)	.1656
		Carbonic anhydrid (CO_2)	.7761
		Water (H_2O)	.1703
		Oxygen equivalent	.0043
		Organic matter	trace
		Total	1.7684

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid ($NaCl$)	.0262	1.528
Calcium sulfate ($CaSO_4$)	.0585	3.411
Calcium bicarbonate ($CaH_2(CO_3)_2$)	1.0084	58.808
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.4496	26.220
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0601	3.505
Silica (SiO_2)	.1656	9.657
Organic matter	trace	trace
Totals	1.7684	103.129

Free carbon dioxid	trace.
Free hydrogen sulfid	trace.

Analysis by E. H. S. Bailey and D. F. McFarland.

Forest Lake Iron Spring, Bonner Springs.

A short distance west of the lake, just below the drive which runs to the lake, and near the dwelling occupied by the keeper, is another of the numerous iron springs of this vicinity. It is walled up and enclosed, and the water that escapes below is of the peculiar reddish color so commonly observed where iron and certain algæ abound in the waters. The taste of the water is agreeable, with perhaps less iron and sulfur than that of the well previously noticed.

FOREST LAKE IRON SPRING.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0010	Sodium oxid (Na_2O)	.0014
Calcium (Ca)	.1804	Calcium oxid (CaO)	.2526
Magnesium (Mg)	.0241	Magnesium oxid (MgO)	.0404
Iron (Fe)	.0283	Iron oxid (FeO)	.0364
Chlorin (Cl)	.0016	Chlorin (Cl)	.0016
Sulfuric acid ion (SO_4)	.0252	Sulfuric anhydrid (SO_3)	.0212
Silicic acid ion (SiO_3)	.0729	Silica (SiO_2)	.0575
		Carbonic anhydrid (CO_2)	.5073
		Water (H_2O)	.1031
		Oxygen equivalent	.0003
		Total	1.0212

View on Forest Lake, Bonner Springs.

Parkhurst's Iron Spring, Independence.

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0026	.152
Calcium sulfate ($CaSO_4$)	.0360	2.104
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.6878	40.181
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.1473	8.501
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0900	5.263
Silica (SiO_2)	.0575	3.369
Totals	1.0212	59.570
Temperature	13.8° C. (57° F.)	

Analysis by E. H. S. Bailey and D. F. McFarland.

Bonner Springs.

Some of the springs in the park, referred to in chapter XIII, are chalybeate in character, as the following analyses show:[77]

BONNER SPRING NO. 4.

IONS.	Grams per liter.
Calcium (Ca)	.0802
Magnesium (Mg)	.0096
Iron (Fe)	.0546
Chlorid (Cl)	trace
Phosphoric acid ion (PO_4)	trace

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Calcium chlorid ($CaCl_2$)	trace	trace
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.3243	18.942
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.0584	3.414
Iron bicarbonate ($FeH_2(CO_3)_2$)	.1735	10.135
Phosphoric acid	trace	trace
Organic matter	trace	trace
Totals	.5562	32.491

Analysis by Wm. Jones, M. D.

BONNER SPRING NO. 5.

IONS.	Grams per liter.
Calcium (Ca)	.0936
Magnesium (Mg)	.0114
Iron (Fe)	.0410
Chlorin (Cl)	trace
Sulfuric acid ion (SO_4)	.0042
Phosphoric acid ion (PO_4)	trace

77. Bull. U. S. Geol. Surv. No. 32.

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Calcium chlorid ($CaCl_2$)	trace	trace
Calcium sulfate ($CaSO_4$)	.0059	.344
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.3720	21.730
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.0696	4.065
Iron bicarbonate ($FeH_2(CO_3)_2$)	.1302	7.603
Phosphoric acid (H_3PO_4)	trace	trace
Organic matter	trace	trace
Totals	.5777	33.742

Analysis by Wm. Jones, M. D.

BONNER SPRING NO. 6.

IONS.	Grams per liter.
Calcium (Ca)	.0578
Magnesium (Mg)	.0254
Iron (Fe)	.0478
Chlorin (Cl)	trace
Sulfuric acid ion (SO_4)	.0073
Phosphoric acid ion (PO_4)	trace

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Calcium chlorid ($CaCl_2$)	trace	trace
Calcium sulfate ($CaSO_4$)	.0103	.605
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.2214	12.929
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.1570	9.172
Iron bicarbonate ($FeH_2(CO_3)_2$)	.1519	8.870
Phosphoric acid	trace	trace
Organic matter	small amt.	small amt.
Totals	.5406	31.576

Analysis by Wm. Jones, M. D.

Coyville Ferro-manganese Well.

About five miles southwest of Coyville, Wilson county, on the farm of Jacob Killion, is a bored well. The attention of the owner was attracted to the character of the water because an "oil" rose on the top after it had stood for a short time. Upon examination in the laboratory, this phenomenon was found to be due to the presence in the water of iron, and also a larger quantity of manganese than is usually found in natural waters. Coyville is on a branch of the Atchison, Topeka & Santa Fe railroad.

COYVILLE FERRO-MANGANESE WATER, WILSON COUNTY.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0260	Sodium oxid (Na_2O)	.0342
Calcium (Ca)	.0168	Calcium oxid (CaO)	.0235
Magnesium (Mg)	.0077	Magnesium oxid (MgO)	.0128
Iron (Fe)	.0117	Iron oxid (FeO)	.0151
Manganese (Mn)	.0198	Manganese oxid (MnO)	.0254
Chlorin (Cl)	.0390	Chlorin (Cl)	.0390
Silicic acid ion (SiO_3)	.0304	Silicic anhydrid (SiO_2)	.0240
		Carbonic anhydrid (CO_2)	.1151
		Water (H_2O)	.0235
		Oxygen equivalent	.0088
		Total	.3038

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0643	3.756
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.0680	3.972
Manganese bicarbonate ($MgH_2(CO_{3,2})$	.0468	2.734
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0374	2.184
Magnesium bicarbonate ($MnH_2(CO_3)_2$)	.0633	3.697
Silica (SiO_2)	.0240	1.401
Totals	.3038	17.744

Partial analysis by E. H. S. Bailey and F. B. Porter.

Parkhurst Spring, Independence.

This spring is situated on the right bank of the Verdigris river, about a mile and a half northeast of the city of Independence. The river is beautifully shaded at this point, and a footpath leads from the spring to the bank of the river, perhaps fifty feet below. In this vicinity the Verdigris flows over rocks and shallows, and below the city (see cut) its course is turned due east by high, rocky banks. Just east of Independence the water is so deep that it furnishes ample water for a small steamboat and other light craft.

IMPROVEMENTS.

In 1897 a road was constructed from the highway near the residence of Mr. Parkhurst, the owner of this spring, and a small pavilion was erected for the benefit of picnic parties. Beyond this no improvements have been made in the property.

Looking up the Verdigris, Independence.

Louisville Springs.

The spring flows from beneath a sandstone rock, and the water deposits much iron after it comes in contact with the air. The flow of the spring in the dryest weather is about sixty gallons per hour.

PARKHURST SPRING.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0725	Sodium oxid (Na_2O)	.0955
Calcium (Ca)	.3735	Calcium oxid (CaO)	.5231
Magnesium (Mg)	.1668	Magnesium oxid (MgO)	.2784
Manganese (Mn)	.0018	Manganese oxid (MnO)	.0021
Iron (Fe)	.0101	Iron oxid (FeO)	.1325
Sulfuric acid ion (SO_4)	19.9545	Sulfuric anhydrid (SO_3)	1.6718
Silicic acid ion (SiO_3)	.0501	Carbonic anhydrid (CO_2)	.1716
		Hydrogen sulfid (H_2S)	.0014
		Silica (SiO_2)	.0393
		Total	2.9157

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium sulfate (Na_2SO_4)	.2187	12.774
Calcium sulfate ($CaSO_4$)	1.5148	88.479
Magnesium sulfate ($MgSO_4$)	.8352	48.784
Manganese bicarbonate ($MnH_2(CO_3)_2$)	.0046	.271
Iron bicarbonate ($FeH_2(CO_3)_2$)	.2952	17.244
Silica (SiO_2)	.0393	2.299
Carbonic anhydrid (CO_2)	.0063	.373
Hydrogen sulfid (H_2S)	.0014	.083
Chlorin, potassium, and lithium	traces	traces
Totals	2.9157	170.307

Analysis by Paul Schweitzer.

La Cygne Iron Spring.

This spring is situated on the west bank of the Marais des Cygnes, near La Cygne, on the property of Mr. Cheagor. The spring is not large, although it seems to be a good chalybeate water. The total solids in the water are 31.326 grains, of which 3.5 grains are ferrous carbonate. There is also a considerable quantity of calcium carbonate and magnesium carbonate, with a small quantity of calcium sulfate, sodium chlorid, and manganese carbonate.

Clarus Spring, Batesville, Woodson County.

This spring is situated on the Fort Scott & Wichita railway, nine miles west of Yates Center. The water comes from beneath a thick limestone ledge. From the situation of the spring, it is probable that there is no opportunity for the water to become in any way contaminated by organic matter. The water, as will be seen by the analysis, belongs to that class of pure waters which are recommended by physicians on account of the fact that they contain so small a quantity of mineral salts. For some time this water was kept on tap at one of the drug-stores in Topeka.

IMPROVEMENTS.

This spring is walled up and cemented, and a small spring-house has been built over it. The flow is about forty gallons per hour. The analysis is given in chapter XVIII.

Lawrence City Water, Douglas County.

The water supplied to the city of Lawrence is practically a chalybeate water. It is obtained from a large well dug in the sand a short distance west of the river, and from points that have been driven into the soil in the vicinity. The water, after it is pumped, is aerated by flowing from the top of a pipe several feet into a reservoir, and it is then allowed to stand in settling basins for some time. This treatment, however, does not fully remove the iron, for, soon after the water is drawn from the service-pipes, it loses its carbon-dioxid gas, becomes par-

tially oxidized, and deposits a yellowish sediment of ferric hydroxid. This water is of entirely different composition from the river water, as repeated analyses have shown. Waters of this character are common in the bottoms of the Kansas and Missouri river valleys, and also in various localities in the great Mississippi basin, as has been noticed by several chemists. The sample drawn from the service-pipes does not show the full amount of iron found in the well.

LAWRENCE CITY WATER-SUPPLY.

Water from tap at chemistry building December 20, 1901.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0736	Sodium oxid (Na_2O)	.0993
Calcium (Ca)	.1256	Calcium oxid (CaO)	.1759
Magnesium (Mg)	.0259	Magnesium oxid (MgO)	.0433
Iron (Fe)	.0098	Iron oxid (FeO)	.0126
Chlorin (Cl)	.0920	Chlorin (Cl)	.0920
Sulfuric acid ion (SO_4)	.1063	Sulfuric anhydrid (SO_3)	.0902
Silicic acid ion (SiO_3)	.0555	Silicic anhydrid (SiO_2)	.0446
		Carbonic anhydrid (CO_2)	.3145
		Water (H_2O)	.0641
		Oxygen equivalent	.0207
		Total	.9158

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.1518	8.861
Sodium sulfate (Na_2SO_4)	.0428	2.501
Calcium sulfate ($CaSO_4$)	.1123	6.551
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.3750	21.902
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.1582	9.241
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0311	*1.830
Silica (SiO_2)	.0446	2.605
Totals	.9158	53.491

Analysis by E. Bartow and J. S. Worley.

*Analyses of water from the reservoir direct have shown considerably over two grains.

Suspension Bridge, Louisville.

Bathing in Rock Creek, Louisville Springs.

Louisville Springs.

In Pottawatomie county, three miles north of Wamego, are situated the Louisville mineral springs. These are not far from Rock creek, a picturesque stream whose banks are well wooded. Wamego is on the main line of the Union Pacific railroad.

IMPROVEMENTS.

A park, which is the property of R. M. Chilcott, is connected with the village by a suspension foot bridge over Rock creek. Just below this bridge a dam has been thrown across the stream, and the swift water below the dam, at a ford on the old Pike's Peak trail, has washed away the soil and left bare the level limestone rock over a large area. This same stratum of rock that is here exposed extends northwest under the park and springs. On account of the level, smooth bottom in the pool below the dam, this pool is a favorite bathing place, especially when the water in the stream is high. Above the dam the slack water, which extends up about five miles, affords excellent boating and fishing facilities.

By sinking over the spring a tile twenty-four inches in diameter down to bed-rock, the spring-water has been made more accessible, and can be raised to a platform above by an ordinary pump. Although the water when first drawn is perfectly clear and transparent, in a short time it becomes yellow in color and very turbid. Boiling the water also causes a heavy deposit. The taste of the water is somewhat astringent, and occasionally it has a slight odor of hydrogen sulfid when it is freshly drawn. The water when evaporated has a somewhat alkaline reaction.

The analysis shows that the water is chalybeate, and also belongs to the class known as alkaline waters. From a medicinal point of view, its most important ingredients are magnesium bicarbonate, iron bicarbonate, and sodium sulfate. This water has the advantage of containing sodium salts not mixed with a large excess of salt, as is the case with many magnesium waters. On account of the presence of iron bicarbonate in the water, it is not adapted to shipping without being first carbonated. There are other chalybeate springs in this park

the waters of which have not been analyzed. A few rods below the ford, on the right bank of the stream, there is a spring of extremely pure water flowing from beneath the limestone rock. Like some other pure waters that have been found in this state, it would probably be valuable in the treatment of diseases where an abundance of soft water is required.

LOUISVILLE SPRING.[78]

Grams per liter.

IONS.		RADICALS.	
Potassium (K)	.0043	Sodium oxid (Na_2O)	.0805
Sodium (Na)	.0597	Potassium oxid (K_2O)	.0052
Calcium (Ca)	.2709	Calcium oxid (CaO)	.3817
Magnesium (Mg)	.0558	Magnesium oxid (MgO)	.0932
Iron (Fe)	.0198	Iron oxid (FeO)	.0255
Chlorin (Cl)	.0385	Chlorin (Cl)	.0385
Sulfuric acid ion (SO_4)	.1544	Sulfuric anhydrid (SO_3)	.1389
Nitric acid ion (NO_3)	trace	Nitric anhydrid (N_2O_5)	trace
Silicic acid ion (SiO_3)	.0587	Silica (SiO_2)	.0464
		Water (H_2O)	.1558
		Carbonic anhydrid (CO_2)	.7632
		Oxygen equivalent	.0090
		Total	1.7199

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0636	3.7148
Sodium nitrate ($NaNO_3$)	trace	trace
Sodium carbonate ($NaHCO_3$)	.0193	1.1273
Sodium sulfate (Na_2SO_4)	.0996	5.8176
Potassium sulfate (K_2SO_4)	.0096	.5607
Calcium sulfate ($CaSO_4$)	.1324	7.7334
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.9465	55.2855
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.3393	19.8185
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0632	3.6915
Silica (SiO_2)	.0464	2.7102
Totals	1.7199	100.4593
Temperature	13.3° C. (56° F.)	

Analysis by E. H. S. Bailey.

78. Kans. Univ. Quart., vol. VI, pp. 117-119.

The Ford, Louisville Springs.

Topeka Mineral Wells.

Mahaska Well, Washington County.

This well is on the property of J. L. Summers, on the bank of a ravine, bordering the high prairie. The well is twenty feet deep, and is dug down to the solid rock. When this rock was reached it was drilled through with a hand drill, and the well filled rapidly to the depth of twelve feet.

This is a sulfate water containing small quantities of carbonates of lime and magnesia. It is slightly astringent in taste, on account of the iron that is present. One liter, on evaporation, leaves 159.27 grains of mineral matter, so the water contains a considerable quantity of sulfates. When first drawn the water is clear, but soon becomes yellow and turbid from the precipitation of iron. On this account the use of the water for household purposes has been abandoned, although it is still used for watering stock.

Muscotah Artesian Wells, Atchison County.[79]

BY E. B. KNERR.

"Along the base of the east bluff of the Grasshopper valley, about one and a half miles south of Muscotah, on the Central Branch Missouri Pacific railroad, there is a series of interesting low, marshy mounds. The mounded area on the farm of Mr. H. M. Rice is about one hundred rods long by fifteen rods wide, and the mounds are from five to eight feet high. About a quarter of a mile further south, on S. H. Hubbard's farm, is another mound, about fifteen yards wide, sixty yards long, and eight or ten feet high. Two miles further south, on James Miller's place, there are similar mounds. A swamp is usually low ground, but here the swampy ground is the highest.

"Early in September, 1900, Mr. Rice concluded that if he were to sink a pipe near one of these mounds, he would get an artesian flow of water. He bored a test hole with a two-inch auger, and at a depth of thirty-four feet struck a flow of water so strong as to force up pebbles the size of a hickory-nut. A two-inch pipe was forced into the hole, and the water rose to overflow

79. Trans. Kans. Acad. Sci., vol. XVII, pp. 53, 54.

this when it stood fifteen feet above ground. The flow from this two-inch pipe is fifty gallons every fifty-five seconds. The water is as clear as crystal, very palatable, and cold. The water deposits a slight iron coating over the barrel into which it flows. Calcareous deposits are also found in places about the mound, indicating mineral properties for the water.

"The formation of mounds is explained by the water pressure carrying up sand and soil and depositing it at the surface. The mounds are covered by bulrushes, cat-tails and other usual swamp growth, which holds the soil, preventing its being washed down. The water springs from over the whole surface of the mound, and runs away in small streams. Thus the peculiar circumstance arises that the swamp is high ground and the firm soil is lower."

ARTESIAN WELL, MUSCOTAH.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0181	Sodium oxid (Na_2O)	.0244
Potassium (K)	.0203	Potassium oxid (K_2O)	.0245
Calcium (Ca)	.1160	Calcium oxid (CaO)	.1625
Magnesium (Mg)	.0214	Magnesium oxid (MgO)	.0356
Iron (Fe)	.0360	Iron oxid (FeO)	.0454
Chlorin (Cl)	.0176	Chlorin (Cl)	.0176
Sulfuric acid ion (SO_4)	.0660	Sulfuric anhydrid (SO_3)	.0550
Silicic acid ion (SiO_3)	.0305	Silicic anhydrid (SiO_2)	.0280
		Carbonic anhydrid (CO_2)	.3644
		Water (H_2O)	.0746
		Oxygen equivalent	.0040
		Total	.8280

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0290	1.6907
Sodium sulfate (Na_2SO_4)	.0206	1.2010
Potassium sulfate (K_2SO_4)	.0453	2.6410
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.4702	27.4126
Magnesium sulfate ($MgSO_4$)	.0339	1.9764
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.0887	5.1712
Iron bicarbonate ($FeH_2(CO_3)_2$)	.1123	6.5471
Silica (SiO_2)	.0280	1.6324
Totals	.8280	48.2724

Temperature 13.3° C. (56° F.)

Analysis by E. B. Knerr.

Topeka Mineral Well.

This well, which is in the rear of 316 Harrison street, was bored through thirty feet of soil and twenty-five feet of rock. The well above the rock is three feet in diameter and the pump is cemented to the opening in the rock.

IMPROVEMENTS.

Improvements are a commodious bath hotel with a pumping plant, tanks, arrangements for heating the water, cooling rooms, etc. Special attention has been paid to giving steam and Russian baths. The water is all used commercially.

TOPEKA MINERAL WELL.[80]

IONS.	Grams per liter.
Sodium (Na)	.2803
Ammonium	.0070
Calcium (Ca)	.0953
Magnesium (Mg)	.1003
Iron (Fe)	.1514
Aluminum (Al)	.0036
Chlorin (Cl)	.3732
Sulfuric acid ion (SO_4)	.4385
Silicic acid ion (SiO_3)	.2230
Phosphoric acid ion (PO_4)	trace
Nitric acid ion (NO_3)	.0244

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium sulfate (Na_2SO_4)	.3296	19.25
Sodium nitrate ($NaNO_3$)	.0332	1.94
Sodium bicarbonate ($NaHCO_3$)	.6109	35.68
Ammonium sulfate ($(NH_4)_2SO_4$)	.0256	1.50
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.3853	22.51
Magnesium chlorid ($MgCl_2$)	.2016	11.78
Magnesium sulfate ($MgSO_4$)	.2465	14.40
Iron bicarbonate ($FeH_2(CO_3)_2$)	.4811	28.10
Alumina (Al_2O_3)	.0068	.40
Silica (SiO_2)	.1765	10.30
Organic matter	.0302	1.76
Phosphoric acid (H_3PO_4)	trace	trace
Totals	2.5273	147.62

Temperature .... 15° C. (59° F.)

Analysis by Barnes and Sim.

80. Miueral Waters of the United States, Crook, pp. 246, 247.

Capital Mineral Well, Topeka.

This well is situated at 1018 Kansas avenue, in the thickly populated portion of the city. The well is seventy feet back from the street, on high land. It is 122 feet deep, the first twenty feet being bored through compact earth and clay, and the remaining 102 feet through rock and seams of earth. The water is supposed to come from a point 100 feet below the surface. It is sold to customers in the city of Topeka. The proprietor of the well is John W. Newbury.

CAPITAL WELL.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.3608	Sodium oxid (Na_2O)	.4858
Calcium (Ca)	.1832	Calcium oxid (CaO)	.2559
Magnesium (Mg)	.0713	Magnesium oxid (MgO)	.1183
Iron (Fe)	.0865	Iron oxid (FeO)	.1113
Chlorin (Cl)	.3200	Chlorin (Cl)	.3200
Sulfuric acid ion (SO_4)	.2224	Sulfuric anhydrid (SO_3)	.1710
Silicic acid ion (SiO_3)	.3098	Silica (SiO_2)	.2400
		Organic matter	trace
		Carbonic anhydrid (CO_2)	.8810
		Water (H_2O)	.1640
		Oxygen equivalent	.0755
		Total	2.6718

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.4997	29.1874
Sodium sulfate (Na_2SO_4)	.3920	22.8967
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.7400	43.2234
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.4320	25.2331
Iron bicarbonate ($FeH_2(CO_3)_2$)	.2751	16.0744
Silica (SiO_2)	.2400	14.0184
Carbonic anhydrid (CO_2)	.0930	5.4321
Organic matter	trace	trace
Totals	2.6718	156.0655

Analysis by J. T. Lovewell.

Topeka Mineral Well.

This well, which is in the rear of 316 Harrison street, was bored through thirty feet of soil and twenty-five feet of rock. The well above the rock is three feet in diameter and the pump is cemented to the opening in the rock.

IMPROVEMENTS.

Improvements are a commodious bath hotel with a pumping plant, tanks, arrangements for heating the water, cooling rooms, etc. Special attention has been paid to giving steam and Russian baths. The water is all used commercially.

TOPEKA MINERAL WELL.[80]

IONS.	Grams per liter.
Sodium (Na)	.2803
Ammonium	.0070
Calcium (Ca)	.0953
Magnesium (Mg)	.1003
Iron (Fe)	.1514
Aluminum (Al)	.0036
Chlorin (Cl)	.3732
Sulfuric acid ion (SO_4)	.4385
Silicic acid ion (SiO_3)	.2230
Phosphoric acid ion (PO_4)	trace
Nitric acid ion (NO_3)	.0244

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium sulfate (Na_2SO_4)	.3296	19.25
Sodium nitrate ($NaNO_3$)	.0332	1.94
Sodium bicarbonate ($NaHCO_3$)	.6109	35.68
Ammonium sulfate ($(NH_4)_2SO_4$)	.0256	1.50
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.3853	22.51
Magnesium chlorid ($MgCl_2$)	.2016	11.78
Magnesium sulfate ($MgSO_4$)	.2465	14.40
Iron bicarbonate ($FeH_2(CO_3)_2$)	.4811	28.10
Alumina (Al_2O_3)	.0068	.40
Silica (SiO_2)	.1765	10.30
Organic matter	.0302	1.76
Phosphoric acid (H_3PO_4)	trace	trace
Totals	2.5273	147.62

Temperature .... 15° C. (59° F.)

Analysis by Barnes and Sim.

80. Mineral Waters of the United States, Crook, pp. 246, 247.

Capital Mineral Well, Topeka.

This well is situated at 1018 Kansas avenue, in the thickly populated portion of the city. The well is seventy feet back from the street, on high land. It is 122 feet deep, the first twenty feet being bored through compact earth and clay, and the remaining 102 feet through rock and seams of earth. The water is supposed to come from a point 100 feet below the surface. It is sold to customers in the city of Topeka. The proprietor of the well is John W. Newbury.

CAPITAL WELL.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.3608	Sodium oxid (Na_2O)	.4858
Calcium (Ca)	.1832	Calcium oxid (CaO)	.2559
Magnesium (Mg)	.0713	Magnesium oxid (MgO)	.1183
Iron (Fe)	.0865	Iron oxid (FeO)	.1113
Chlorin (Cl)	.3200	Chlorin (Cl)	.3200
Sulfuric acid ion (SO_4)	.2224	Sulfuric anhydrid (SO_3)	.1710
Silicic acid ion (SiO_3)	.3098	Silica (SiO_2)	.2400
		Organic matter	trace
		Carbonic anhydrid (CO_2)	.8810
		Water (H_2O)	.1640
		Oxygen equivalent	.0755
		Total	2.6718

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.4997	29.1874
Sodium sulfate (Na_2SO_4)	.3920	22.8967
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.7400	43.2234
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.4320	25.2331
Iron bicarbonate ($FeH_2(CO_3)_2$)	.2751	16.0744
Silica (SiO_2)	.2400	14.0184
Carbonic anhydrid (CO_2)	.0930	5.4321
Organic matter	trace	trace
Totals	2.6718	156.0655

Analysis by J. T. Lovewell.

Wetmore, Nemaha County.

The Wetmore mineral springs, which have been known for over thirty years, are situated inside the city limits of Wetmore, not more than a quarter of a mile from the center of the town. There is one large spring here and several small ones. A building is being erected here for the bottling works and bath-house by the Wetmore Springs Mineral Water Company, under the direction of Chas. S. Lochnane. There are good hotels in the town, as well as private boarding-houses. The analysis of the water was made several years ago. Wetmore is on the line of the Central Branch Missouri Pacific railroad, forty-three miles west of Atchison.

WETMORE MINERAL SPRINGS, SPRING NO. 1.

IONS.	Grams per liter.
Sodim (Na)	.0241
Potassium (K)	.0582
Calcium (Ca)	.0888
Magnesium (Mg)	.0807
Iron (Fe)	.0214
Chlorin (Cl)	.0323
Sulfuric acid ion (SO_4)	.2201
Silicic acid ion (SiO_3)	.0289
Phosphoric acid ion (PO_4)	.0033

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0445	2.600
Sodium bicarbonate ($NaHCO_3$)	.0201	1.172
Potassium chlorid (KCl)	.0111	.647
Calcium sulfate ($CaSO_4$)	.1272	7.440
Calcium phosphate ($Ca_3(PO_4)_2$)	.0070	.409
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.1978	11.534
Magnesium sulfate ($MgSO_4$)	.1614	9.433
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.2942	17.197
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0682	3.986
Silica (SiO_2)	.0228	1.330
Organic matter	.0281	1.640
Totals	.9824	57.388

Specific gravity.................. 1.0068
Temperature.................... 10° C. (50° F.)

Analysis by Juan H. Wright, M. D.

COMPARISON OF SIMILAR WATERS.

Grains per gallon.

Excelsior Springs, Mo., Regent Spring.

Analysis by Woodward and Robertson.

Sodium chlorid	2.230	Ferrous bicarbonate	3.438
Potassium chlorid	.670	Manganese bicarbonate	.982
Calcium bicarbonate	28.867	Alumina	.297
Magnesium chlorid	.420	Silica	1.116
Magnesium bicarbonate	3.754	Oxygen	.1998
Magnesium sulfate	.350	Total	42.124

Monroe County, Wisconsin, Spata Artesian Well.

Analysis by J. M. Hirsch.

Sodium chlorid	.112	Calcium carbonate	.232
Sodium sulfate	1.840	Magnesium carbonate	1.992
Sodium carbonate	.120	Strontium carbonate	.008
Sodium phosphate	.056	Ferrous carbonate	8.664
Potassium sulfate	.528	Aluminum phosphate	.048
Lithium carbonate	.016	Silica	.232
Calcium chlorid	.504	Total	14.496
Calcium sulfate	.144		

Rock Enon Springs, Frederick County, Virginia, Copper Spring.

Analysis by Gale and Mew.

Sodium carbonate	1.21	Ferrous carbonate	14.25
Calcium sulfate	3.56	Manganese carbonate	1.05
Calcium carbonate	5.13	Alumina	.80
Magnesium chlorid	1.12	Silica	.42
Magnesium sulfate	12.89	Total	40.43

Schwalbach, Germany, Stahlbrunnen.

Analysis by Fresenius.

Sodium sulfate	.461	Magnesium bicarbonate	14.138
Sodium bicarbonate	1.347	Manganese bicarbonate	1.196
Potassium sulfate	.216	Ferrous bicarbonate	5.445
Potassium chlorid	.391	Silica	1.869
Calcium bicarbonate	14.542	Total	39.605

Marienbad, Germany, Ambrosius brunn.

Analysis by Gintl.

Sodium chlorid	.806	Magnesium chlorid	1.466
Sodium sulfate	18.189	Magnesium bicarbonate	16.863
Sodium bicarbonate	4.824	Iron bicarbonate	9.737
Sodium nitrate	.041	Manganese bicarbonate	.146
Potassium sulfate	2.021	Aluminous phosphate	.309
Lithium carbonate	.041	Silica	2.909
Calcium sulfate	2.675	Carbon dioxid (free)	134.010
Calcium bicarbonate	17.534	Total	211.571

There are some waters that contain larger amounts of iron than those just mentioned, but, on account of the presence in these waters of much sulfuric acid, the iron is usually considered to be combined as iron sulfate. Aluminum sulfate is very often present in large quantities in these waters, as they may be formed by the decomposition and oxidation of shale containing pyrite. The latter on being oxidized furnishes both the iron and the sulfate ion. The excess of the sulfate dissolves the alumina in the shale. The following may be considered as typical waters of this class, and are classified as chalybeate by many authors:

Bath Alum Springs, Virginia, No. 2.

Analysis by W. H. Taylor.

Sodium chlorid	.11	Manganese sulfate	.03
Sodium sulfate	1.13	Aluminum sulfate	29.99
Potassium sulfate	.34	Sulfuric acid	2.88
Calcium sulfate	1.71	Silica	1.95
Magnesium sulfate	.46	Total	65.38
Iron persulfate	26.78		

Brighton, England.

Analysis by Marcet.

Sodium chlorid	12.24	Silica	1.12
Calcium sulfate	32.72	Loss	1.52
Magnesium chlorid	6.00	Total	68.00
Ferrous sulfate	14.40		

Carbon dioxid .... 20 cubic inches.

A Comparison of Some of the Waters of the *Iron* Group.

These waters are mainly carbonates, containing larger quantities of iron than usual. The other substances of importance are calcium and magnesium bicarbonates. The amount of iron bicarbonate in the different waters discussed is as follows:

Grains per gallon.

Lawrence city supply	1.830	Muscotah	6.547
Coyville	2.184	Arrington No. 3	7.044
Coyville, $MnH_2(CO_3)_2$	3.697	Bonner No. 5	7.603
Arrington No. 2	3.084	Bonner No. 6	8.870
McDuff's spring	3.109	Bonner No. 4	10.135
Forest Lake well	3.505	Atchison electric light	12.511
Louisville	3.691	Capital	16.074
Wetmore	3.986	Parkhurst	17.244
Forest Lake spring	5.263	Parkhurst, $MnH_2(CO_3)_2$	.271
Arrington No. 1	5.484		
Regent, Excelsior Springs, Mo.	3.483	Sparta, Wis.	8.644
Regent, Excelsior Springs, Mo., $MnH_2(CO_3)_2$	.982	Marienbad, Germany	9.734
Schwalbach, Germany	5.445	Marienbad, $MnH_2(CO_3)_2$	.146
Schwalbach, Germany, $MnH_2(CO_3)_2$	1.196	Rock Enon, Va	14.250
Bath Alum, Va., (iron persulfate)	26.78	Brighton, England (ferrous sulfate)	26.78

CHAPTER XVII.

Special Group.

There has been, and in fact still is, considerable discussion as to the action on the system of those substances present in small quantity in waters. If we hold to the theory that the therapeutic action comes mostly from the ions, then the effect may not be as insignificant as would at first appear. (See chapter V.)

It is no doubt true that this special group might be greatly enlarged if a more complete analysis had been made of some of the waters of the state. One has but to study the very complete analyses of the waters of the Yellowstone Park,[81] in which in some cases the search for rare elements was extended to include lithium, boric acid, barium, strontium, ammonium, cæsium, rubidium, and manganese, to see what a more complete analysis will reveal. It would be surprising if further investigation did not show an equally large variety of elements in the Kansas waters.

The special substances considered in this group are lithium, barium, strontium, bromin, iodin, flourin, boric acid, and arsenic, and their therapeutic qualities have been previously considered. (See chapter III.)

This group is represented by the following waters:

Baxter Springs, Cherokee county, No. 1.

Baxter Springs, Cherokee county, No. 5.

Fort Scott, Bourbon county, artesian well.

Rosedale, Johnson county, geyser well.

Independence, Montgomery county, brom-magnesian well.

Jewell county, lithia spring.

Providence, Butler county.

81. Bull. U. S. Geol. Surv. No. 47, Gooch and Whitfield.

Baxter Springs, No. 1, "Iron Spring."

For description, see chapter XIII.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0117	Sodium oxid (Na_2O)	.0158
Potassium (K)	.0045	Potassium oxid (K_2O)	.0055
Lithium (Li)	.0004	Lithium oxid (Li_2O)	.0009
Calcium (Ca)	.1353	Calcium oxid (CaO)	.1894
Magnesium (Mg)	.0670	Magnesium oxid (MgO)	.1116
Iron (Fe)	.0035	Iron oxid (FeO)	.0045
Chlorin (Cl)	.0141	Chlorin (Cl)	.0141
Sulfuric acid ion (SO_4)	.1711	Sulfuric anhydrid (SO_3)	.1426
Silicic acid ion (SiO_3)	.0149	Silica (SiO_2)	.0118
		Water (H_2O)	.0825
		Carbonic anhydrid (CO_2)	.4045
		Oxygen equivalent	.0032
		Total	.9800

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0164	.9579
Sodium sulfate (Na_2SO_4)	.0161	.9404
Potassium chlorid (KCl)	.0087	.5082
Lithium bicarbonate ($LiHCO_3$)	.0041	.2395
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.5480	32.0086
Magnesium sulfate ($MgSO_4$)	.2001	11.6878
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.1637	9.5617
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0111	.6485
Silica (SiO_2)	.0118	.6892
Totals	.9800	57.2418

Analysis by E. B. Knerr.

Baxter Springs No. 5, Newhouse Spring.

For description, see chapter XIII.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0171	Sodium oxid (Na_2O)	.0232
Potassium (K)	.0165	Potassium oxid (K_2O)	.0200
Lithium (Li)	.0002	Lithium oxid (Li_2O)	.0005
Calcium (Ca)	.0895	Calcium oxid (CaO)	.1252
Magnesium (Mg)	.0101	Magnesium oxid (MgO)	.0169
Iron (Fe)	.0022	Iron oxid (FeO)	.0029
Nitrous acid ion (NO_2)	.0001	Chlorin (Cl)	.0344
Nitric acid ion (NO_3)	.0124	Nitrous anhydrid (N_2O_3)	.0001
Sulfuric acid ion (SO_4)	.0621	Nitric anhydrid (N_2O_5)	.0093
Silicic acid ion (SiO_3)	.0150	Sulfuric anhydrid (SO_3)	.0518
		Silica (SiO_2)	.0150
		Water (H_2O)	.0371
		Carbonic anhydrid (CO_2)	.1819
		Oxygen equivalent	.0070
		Total	.5113

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0436	2.5467
Potassium chlorid (KCl)	.0166	.9696
Potassium nitrite (KNO_2)	.0001	.0058
Potassium nitrate (KNO_3)	.0202	1.1799
Lithium bicarbonate ($LiHCO_3$)	.0019	.1110
Calcium sulfate ($CaSO_4$)	.0307	1.7932
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.3256	19.0183
Magnesium sulfate ($MgSO_4$)	.0505	2.9497
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0071	.4147
Silica (SiO_2)	.0150	.8761
Totals	.5113	29.8650

Analysis by E. B. Knerr.

Lithium Spring, Omio, Jewell County.[82]

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.1861	Sodium oxid (Na_2O)	.2509
Potassium (K)	.2826	Potassium oxid (K_2O)	.3406
Lithium (Li)	.0053	Lithium oxid (Li_2O)	.0115
Calcium (Ca)	.4753	Calcium oxid (CaO)	.6654
Magnesium (Mg)	.7135	Magnesium oxid (MgO)	1.1892
Iron (Fe)	trace	Iron oxid (FeO)	trace
Aluminum (Al)	.1029	Aluminum oxid (Al_2O_3)	.1940
Chlorin (Cl)	.1491	Chlorin (Cl)	.1491
Sulfuric acid ion (SO_4)	5.0640	Sulfuric anhydrid (SO_3)	4.2200
Boric acid ion (B_4O_7)	.0065	Boric anhydrid (B_4O_6)	.0039
Silicic acid ion (SiO_3)	.1090	Silicic anhydrid (SiO_2)	.0862

Analysis by G. H. Failyer and J. T. Willard.

Providence Mineral Well.

This well is situated at Providence, Richland township, in the southwest corner of Butler county. It is nine miles east of Mulvane, on the Santa Fe railroad, and six miles southwest of Douglass, on a branch of the same line. In 1873 C. F. Dunnell bored for water on the divide between Walnut and Maple creeks, and, striking rock at a depth of ten feet, he blasted it for thirty feet and then bored with a six-inch drill, when, at the depth of 144 feet, the drill dropped into a white sand and water rose in the well to a depth of eighty-four feet.

This water was found to contain considerable mineral matter, so the well was abandoned; but later the water was tried for medicinal purposes by the farmers in the vicinity, with such satisfactory results that the owner erected a windmill for pumping the water and began selling it to his customers. There is an abundance of free carbon-dioxid gas in the water, which makes it quite satisfactory as a beverage. This might also be classified as a chlor-sulfate water.

IMPROVEMENTS.

On this property, which is owned by Mrs. Laura F. Wright (Douglass P. O.), is a hotel with ten rooms for lodging, and dining-room, with spacious verandas. Two dwellings and a

82. Trans. Kans. Acad. Sci., vol. X, p. 63.

bath-house with four baths have been erected. At one time the water was kept on draft in Wichita, both in the natural condition and carbonated, but recently no attempt has been made to utilize the water.

PROVIDENCE MINERAL WELL.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.4300	Sodium oxid (Na_2O)	.5690
Potassium (K)	.0367	Potassium oxid (K_2O)	.0442
Lithium (Li)	.0299	Lithium oxid (Li_2O)	.0069
Barium (Ba)	trace	Barium oxid (BaO)	trace
Strontium (Sr)	trace	Strontium oxid (SrO)	trace
Calcium (Ca)	.6195	Calcium oxid (CaO)	.8696
Magnesium (Mg)	.1534	Magnesium oxid (MgO)	.2555
Iron (Fe)	.0027	Iron oxid (FeO)	.0035
Aluminum (Al)	trace	Aluminum oxid (Al_2O_3)	trace
Chlorin (Cl)	.5263	Chlorin (Cl)	.5263
Sulfuric acid ion (SO_4)	2.0354	Sulfuric anhydrid (SO_3)	1.6957
Phosphoric acid ion (PO_4)	trace	Phosphoric anhydrid (PO_3)	trace
Carbonic acid ion (CO_3)	.6300	Carbonic anhydrid (CO_2)	.2743
Silicic acid ion (SiO_3)	.0511	Water (H_2O)	.0564
Organic matter	trace	Silica (SiO_2)	.0403
		Organic matter	trace
		Oxygen equivalent	.1189
		Total	4.2228

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.8682	50.712
Sodium sulfate (Na_2SO_4)	.2477	14.468
Sodium phosphate (Na_2PO_4)	trace	trace
Potassium sulfate (K_2SO_4)	.0817	4.772
Lithium bicarbonate ($LiHCO_3$)	.0315	1.839
Calcium sulfate ($CaSO_4$)	2.1031	122.842
Barium bicarbonate ($BaH_2(CO_3)_2$)	trace	trace
Strontium bicarbonate ($SrH_2(CO_3)_2$)	trace	trace
Magnesium sulfate ($MgSO_4$)	.4241	24.771
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.4176	24.392
Iron bicarbonate ($FeH_2(CO_3)_2$	.0086	.502
Aluminum oxid (Al_2O_3)	trace	trace
Silica (SiO_2)	.0403	2.355
Organic matter	trace	trace
Totals	4.2228	246.653

Analysis by J. H. Banks.

COMPARISON OF SIMILAR WATERS.

Lithium, as previously noted, is not an abundant element. The amount found in some waters is as follows:

	Grains per gallon.
Geneva Springs, New York	1.55
Champion Spouting Spring, Saratoga, New York	.62
Congress (Saratoga)	.47
Geyser, spouting (Saratoga)	.90
United States (Saratoga)	.48
Artesian lithia, Ballston, N. Y.	.77
Artesian well, Ballston, N. Y.	.56
Franklin well, Ballston, N. Y.	.67
Condo-detonean, Ballston, N. Y.	.76
Bonifacias, Salzschliff, Germany	4.49
Temple brunnen, Germany	3.36
Kreutznach, Germany, Elisabeth quelle	1.35
Baden-Baden, Germany, Haupt Stollan	1.12
Kissingen, Germany	.53

Bromids and iodids, although never present in large quantities, are regarded of great importance, on account of their therapeutic action. The amount of bromin and iodin, calculated as grains per gallon, in some well-known waters, is mentioned below.

	Bromin.	Iodin.
Ocean water	24.20	
Dead Sea	121.50	
Saratoga, N. Y.:		
Congress	6.72	.12
Champion Spouting	2.78	.19
Excelsior		3.59
Washington		1.90
Ballston, N. Y.:		
Artesian lithia	2.83	.10
Franklin artesian	3.60	.20
Condo-detonean	1.83	.18
Sans Souci	.....	1.17
Watkins, N. Y.: Deerlick Spring	.46	.03
Kentucky:		
Green Springs	11.24	
Upper Blue Lick	2.96	.13
Virginia: Jordan, alum		.60
West Virginia: Iodin spring	.65	.63
Canada:		
Saline, Ontario	.76	.07
Caxton, Springs	1.55	
Germany:		
Csiz, Hygiea	7.18	2.45
Hall, Tassilo	4.14	1.51
Heilbrunn, Adelhaid	.38	1.47
Salzbrunn, Römer	.....	.82
Kreuznach, Oranien	11.74	.05
Salzschliff, Grossluderer	6.89	
Kissingen, Bitterwasser	5.78	
Baden-Baden, Büll	.58	

CHAPTER XVIII.

Soft-water Group.

These are called by some "indifferent" and by others "neutral" waters. Some of these contain even less than a grain of solid matter to the gallon. They are frequently of great value as therapeutic agents, especially for persons who have been accustomed to drinking hard waters. As stated in the chapter on therapeutics, often the most important thing about these waters is that they contain so few mineral ingredients.

A good example of this class of waters is that of Pfeffer's Springs, where Martin Luther is said to have spent considerable time, and where he was cured of hypochondriasis. The waters of Wildbad, in Wurtemburg, are of this class. These, we know from Roman remains that have been found in the vicinity, were used even as early as the time of the Cæsars.

One reason why such waters are of value in diseases like constipation is, that the patient is induced to drink very large quantities of water, and this not only renders the contents of the intestines more fluid, but it helps to wash out the body. If the patient was not so situated that his attention was directed to the drinking of water, he would not use a sufficient quantity.

The diuretic action of large quantities of water is well established. It also increases the quantity of urea, phosphates, chlorids and sulfates that are discharged. If large quantities of water are taken, the temperature of the body falls, and the number of pulsations of the heart and of the inspirations are diminished.

This group is represented by the following waters:

Atchison, Parker's spring.

Brookville spring, Saline county.

Brookville No. 2.
California spring, Franklin county.
Cave spring, Galena, (Jasper county, Missouri.)
Chautauqua, Chautauqua county.
Chico spring, Galena, Cherokee county.
Clarus spring, Batesville, Woodson county.
Conway Springs, Sumner county.
Delaware springs, Wilson county.
Linwood spring, Leavenworth county.
Sand springs, Dickinson county.

Atchison, Parker's Spring.

About two miles west of the city of Atchison, on the farm of J. W. Parker, is a fine spring that has been known for many years. It supplies the farm with an abundance of water.

PARKER'S SPRING.

IONS.		RADICALS.	
Sodium (Na)	trace	Sodium oxid (Na_2O)	trace
Potassium (K)	.0056	Potassium oxid (K_2O)	.0067
Calcium (Ca)	.0212	Calcium oxid (CaO	.0297
Magnesium (Mg)	.0036	Magnesium oxid (MgO)	.0060
Iron (Fe)	.0009	Iron oxid (FeO)	.0012
Aluminum (Al)	.0017	Aluminum oxid (Al_2O_3)	.0032
Nitric acid ion (NO_3)	.0175	Nitric anhydrid (N_2O_5)	.0152
Chlorin (Cl)	.0063	Chlorin (Cl)	.0063
Sulfuric acid ion (SO_4)	.0053	Sulfuric anhydrid (SO_3)	.0044
Phosphoric acid ion (PO_4)	trace	Phosphoric anhydrid (P_2O_5)	trace
Silicic acid ion (SiO_3)	.0253	Silica (SiO_2)	.0200
		Water (H_2O	.0104
		Carbonic anhydrid (CO_2)	.0508
		Oxygen equivalent	.0014
		Total	.1525

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Potassium nitrate (KNO_3)	.0144	.8398
Calcium nitrate ($Ca(NO_3)_2$)	.0115	.6686
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.0745	4.3470
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.0147	.8584
Magnesium chlorid ($MgCl_2$)	.0047	.2727
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0029	.1730
Aluminum chlorid ($AlCl_3$)	.0035	.2030
Aluminum sulfate ($Al_2(SO_4)_3$)	.0063	.3657
Silica (SiO_2)	.0200	1.1666
Totals	.1525	8.8948

Temperature .... 16.6° C. (62° F.)

Analysis by E. B. Knerr.

Brookville Spring No. 1.

A remarkably pure water from about seven miles west of Brookville has been examined. It is clear, colorless, and of an agreeable taste. It contains only 8.097 grains of solid matter per gallon, which consists of calcium bicarbonate, calcium sulfate, sodium chlorid, with traces of silica, alumina, and magnesium bicarbonate.

Another water from Brookville, which was examined in June, 1887, contains only 3.48 grains per gallon of mineral matter. This consists quite largely of silica, with small quantities of iron and aluminum, and traces of calcium and magnesium bicarbonate, sodium chlorid, and sodium nitrate. This water is remarkably free from mineral matter, and is in fact one of the purest waters so far noticed in the state. As will be seen, it contains no more mineral matter than waters from the granite and sandstone ledges of the extreme Eastern states.

California Spring, Norwood, Franklin County.

This spring is on the farm of E. W. Hume, four miles northwest of Ottawa. It is pleasantly situated on the southern slope of the broad valley of the Marais des Cygnes. The flow is 450 gallons per hour. The California spring is said to have derived its name from its situation on one of the numerous trails leading across the state to the mountains and to California. On the unbroken prairie in the vicinity may still be seen numerous well-marked trails, all converging towards this bountiful water-supply. A few barrels of the water were shipped in 1902. That the water is of exceptional purity may be noticed from the analysis which follows:

CALIFORNIA SPRING.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0068	Sodium oxid (Na_2O)	.0092
Calcium (Ca)	.0146	Calcium oxid (CaO)	.0205
Magnesium (Mg)	.0018	Magnesium oxid (MgO)	.0031
Iron (Fe)	.0004	Iron oxid (FeO)	.0005
Chlorin (Cl)	.0106	Chlorin (Cl)	.0106
Sulfuric acid ion (SO_4)	.0074	Sulfuric anhydrid (SO_3)	.0062
Silicic acid ion (SiO_3)	.0238	Silicic anhydrid (SiO_2)	.0180
		Carbonic anhydrid (CO_2)	.0327
		Water (H_2O)	.0067
		Oxygen equivalent	.0024
		Total	.1051

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0174	1.018
Calcium sulfate ($CaSO_4$)	.0106	.618
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.0466	2.721
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.0113	.661
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0012	.071
Silica (SiO_2)	.0180	1.049
Totals	.1051	6.138

Temperature.................. 14.4° C. (58° F.)

Analysis by E. H. S. Bailey and D. F. McFarland.

Cave Spring.

Northeast of Galena, and on the south side of the ridge near the south bank of Spring creek, is a never-failing spring that is of great advantage to the community. In fact, as the city water at Galena is taken from Shoal creek, which drains the mines of the vicinity, and consequently contains both lead and zinc, this spring furnishes one of the best waters that can be obtained for domestic purposes. The flow is at least 400 gallons per hour. The water is hauled to the city, during the summer especially, for a large number of regular customers. About a quarter of a mile south of this, on the other side of the ridge, is Gum spring, which is also utilized in the same way by the people in the vicinity. Galena is reached by the St. Louis & San Francisco system.

CAVE SPRING.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0025	Sodium oxid (Na_2O)	.0034
Calcium (Ca)	.0198	Calcium oxid (CaO)	.0278
Magnesium (Mg)	.0016	Magnesium oxid (MgO)	.0026
Iron (Fe)	.0028	Iron oxid (FeO)	.0036
Chlorin (Cl)	.0028	Chlorin (Cl)	.0028
Sulfuric acid ion (SO_4)	.0344	Sulfuric anhydrid (SO_3)	.0287
Silicic acid ion (SiO_3)	.0227	Silicic anhydrid (SiO_2)	.0179
		Carbonic anhydrid (CO_2)	.0245
		Water (H_2O)	.0049
		Oxygen equivalent	.0006
		Total	.1156

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0046	.2684
Sodium bicarbonate ($NaHCO_3$)	.0028	.1634
Calcium sulfate ($CaSO_4$)	.0399	2.3321
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.0328	1.9140
Magnesium sulfate ($MgSO_4$)	.0087	.5081
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0089	.5201
Silica (SiO_2)	.0179	1.0461
Totals	.1156	6.7522

Temperature .... 15° C. (59° F.)

Analysis by E. H. S. Bailey and E. McCullom.

Chico Spring.

The country in the vicinity of Galena is much diversified and well watered. A mile northwest of this city, in a wooded valley, is the so-called Chico spring. In the high water this spring is covered by the stream, but it ordinarily flows out of the gravel and into the creek. The flow is about 600 gallons an hour in the dryest weather. This water contains traces of zinc.

CHICO SPRING.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0034	Sodium oxid (Na_2O)	.0046
Calcium (Ca)	.0458	Calcium oxid (CaO)	.0642
Magnesium (Mg)	.0068	Magnesium oxid (MgO)	.0113
Iron (Fe)	.0027	Iron oxid (FeO)	.0035
Chlorin (Cl)	.0035	Chlorin (Cl)	.0035
Sulfuric acid ion (SO_4)	.0650	Sulfuric anhydrid (SO_3)	.0544
Silicic acid ion (SiO_3)	.0177	Silicic anhydrid (SiO_2)	.0140
		Carbonic anhydrid (CO_2)	.0835
		Water (H_2O)	.0174
		Oxygen equivalent	.0008
		Total	.2556

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0058	.3384
Sodium bicarbonate ($NaHCO_3$)	.0041	.2392
Calcium sulphate ($CaSO_4$)	.0448	2.6215
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.1443	8.4244
Magnesium ($MgSO_4$)	.0339	1.9810
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0087	.5080
Silica (SiO_2)	.0140	.8170
Totals	.2556	14.9295

Temperature .... 14.8° C. (58.6° F.)

Analysis by E. H. S. Bailey and E. McCullom.

Kansas Clarus Spring, Batesville, Woodson County.

For description, see chapter XVI.

IONS.	Grams per liter.
Sodium (Na)	.0315
Calcium (Ca)	.0492
Magnesium (Mg)	.0065
Iron (Fe)	.0005
Chlorin (Cl)	.0052
Sulfuric acid ion (SO_4)	.0080
Silicic acid ion (SiO_3)	.0085

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0087	.510
Sodium sulfate (Na_2SO_4)	.0119	.695
Sodium bicarbonate ($NaHCO_3$)	.0894	5.210
Calcium bicarbonate ($CaH_2(CO_3)_2$)	.1990	11.605
Magnesium bicarbonate ($MgH_2(CO_3)_2$)	.0397	2.320
Iron bicarbonate ($FeH_2(CO_3)_2$)	.0018	.105
Silica (SiO_2)	.0067	.392
Organic matter	slight trace	slight trace
Totals	.3572	20.837

Temperature............20° C. (68° F.)

Analysis by Church and Lovewell.

Conway Springs, Sumner County.

There were originally seven springs in use in this locality, all within a radius of fifty feet, but the use of all but two has been discontinued. One of these flows at the rate of one gallon per minute, with a temperature of 13.8° C. (57° F.), and the other at the rate of one and one-half gallons per minute, with a temperature of 14.4° C. (78° F.) These springs are encased with twenty-four-inch tiling, and are situated in a pavilion about twenty feet square.

They are located in a five-acre park of Russian mulberry and catalpa trees, and there is a lake, covering perhaps half an acre, below the springs.

The water has been used medicinally for years, and much of it is used in the surrounding county as a table water, but very little has been shipped away. Conway Springs is at a crossing of two lines of the Missouri Pacific railroad.

CONWAY SPRINGS.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0038	Sodium oxid (Na_2O)	.0050
Potassium (K)	.0010	Potassium oxid (K_2O)	.0012
Calcium (Ca)	.0102	Calcium oxid (CaO)	.0143
Magnesium (Mg)	.0022	Magnesium oxid (MgO)	.0037
Iron (Fe)	.0012	Iron oxid (FeO)	.0016
Chlorin (Cl)	.0036	Chlorin (Cl)	.0036
Sulfuric acid ion (SO_4)	.0024	Sulfuric anhydrid (SO_3)	.0020
Phosphoric acid ion (PO_4)	.0090	Phosphoric anhydrid (P_2O_5)	.0067
Silica acid ion (SiO_3)	.0108	Silicic anhydrid (SiO_2)	.0086
		Carbonic anhydrid (CO_2)	.0129
		Total	.0596

Analysis by G. H. Failyer.

This is a remarkably pure water, and contains only 3.48 grains of mineral matter to the gallon.

Delaware Springs.

Extending along the western edge of Wilson county and the eastern edge of Elk county is a range of the Chautauqua hills —bluffs composed of shales and sandstones, and generally covered with scrubby growths of black-jack oak. The sandstones,

which are of varying thickness, are composed of coarse grains of sand, loosely cemented, and often occur quite free from iron, as indicated by the white color of the weathered portions. Where such beds can be found of considerable thickness and extent they serve as natural filters and reservoirs, which supply exceptionally pure water to the wells that may be sunk into them and to the many springs that occur in the ravines cutting down through them. This condition exists in typical form about ten miles northwest of Fredonia, in Wilson county, at what is known as the Delaware spring. The hill upon which the spring occurs is about two miles in length from north to south, and from one to two miles in width. At its northern end the hill terminates in a rocky cliff, showing an exposure of perhaps sixty feet of white sandstone. Three-fourths of a mile south of this a ravine runs to the west, and almost at its very head, and upon its northern slope, the spring appears from a fissure in the sandstone. The flow is not great, but is constant throughout the year, at the rate of a gallon in thirty-five seconds. The water is exceptionally pure, clear, and colorless, and possesses the peculiar but not unpleasant taste that characterizes the finest cistern water.

Two or three other springs appear within a few yards of the one described, but nearer the head of the ravine. One of these, though said by the people of the place to produce "softer" water than that from the Delaware spring, yet contains a large quantity of iron, as evidenced by the heavy brown deposit of ferric hydroxide which coats its channel. The springs have been known for the fine quality of their water ever since the settlement of the country. The Delaware Indians are said to have valued them highly, and catch-basins cut in the sloping face of the sandstone, below the springs, are still shown, which are the reputed work of these people. The water was first used for medicinal purposes about 1893, and has been more or less in demand ever since. Some remarkable cures of kidney and stomach troubles are reported to have followed its use. The place has become a resort for people wanting an outing of a few days, and perhaps a half-dozen families

make their summer camps under the black oaks in the neighborhood. It is also becoming a popular place for holding camp-meetings, Fourth of July celebrations, and old soldiers' reunions. Stella, the nearest postoffice to the Delaware springs, may be reached by a drive of ten miles from Fredonia, the county-seat of Wilson county. The latter town is at the crossing of the A. T. & S. F., the M. P. and the St. L. & S. F. railroads.

DELAWARE SPRINGS.

Grams per liter.

IONS.		RADICALS.	
Sodium (Na)	.0099	Sodium oxid (Na_2O)	.0134
Potassium (K)	.0055	Potassium oxid (K_2O)	.0067
Calcium (Ca)	.0124	Calcium oxid (CaO)	.0143
Magnesium (Mg)	.0067	Magnesium oxid (MgO)	.0111
Iron (Fe)	.0019	Iron oxid (FeO)	.0025
Chlorin (Cl)	.0154	Chlorin (Cl)	.0154
Sulfuric acid ion (SO_4)	.0130	Sulfuric anhydrid (SO_3)	.0109
Nitric acid ion (NO_3)	.0089	Nitric anhydrid (N_2O_5)	.0077
Silicic acid ion (SiO_3)	.0219	Silica (SiO_2)	.0173
		Water (H_2O)	.0077
		Carbonic anhydrid (CO_2)	.0381
		Oxygen equivalent	.0034
		Total	.1417

Hypothetically combined as follows:

	Grams per liter.	Grains per gallon.
Sodium chlorid (NaCl)	.0254	1.4836
Potassium nitrate (KNO_3)	.0144	.8411
Calcium sulfate ($CaSO_4$)	.0185	1.0805
Calcium bicarbonate ($CaH_2(CO_3)_2$	.0194	1.1332
Magnesium bicarbonate ($MgH_2(CO_3)_2$	.0405	2.3656
Iron bicarbonate ($FeH_2(CO_3)_2$	.0062	.3621
Silicate (SiO_2)	.0173	1.0104
Totals	.1417	8.2766

Analysis by E. H. S. Bailey and O. F. Stafford.

Linwood Spring.

On the north side of the Kaw river, about ten miles east of Lawrence and a short distance west of Linwood, in the vicinity of the sandstone outcroppings, is a clear, cold spring of pure water upon the McCarrol place. This water contains 9.9 grains of mineral matter to the gallon, which consists of silica, calcium carbonate, calcium sulfate, sodium chlorid, with traces of magnesium carbonate. This is another good example of a "soft" water.

Sand Springs, Dickinson County.

These springs are situated near the Smoky Hill river, between two and three miles west of Abilene. The water is utilized as the city supply of Abilene, and is used, on account of its purity, on the dining-cars of the Union Pacific railroad. It is one of the very best city supplies in the state. On evaporation the water leaves only 8.152 grains of mineral matter per gallon. This consists essentially of calcium and magnesium carbonates, calcium sulfate, and sodium chlorid. The specific gravity of the water is 1.001. The water is used in large quantities by the Sand Springs Bottling Works in the manufacture of soda-water.

COMPARISON OF SIMILAR WATERS.

The amount of mineral matter contained in some of the so-called "soft" waters of the world is noted below. In the Apalachian and Green Mountain regions of the United States, where the rocks are granite or sandstone, and where there is frequently very little soil through which the water can percolate, the purest waters are found.

	Grains per gallon.
Sheep Rock, Lowell, Mass., artesian well, bored in granite,	.81
Paradise spring, Brunswick, Me.	.99
Pownal spring, West Pownal, Me.	1.15
Pure spring, Cresson, Pa.	1.26
Pavilion spring, Wernersville, Pa.	1.98
Holly spring, Woonsocket, R. I	2.50
Lechauweki spring, Bethlehem, Pa.	3.57
Poland spring, South Poland, Me	3.76
Jordan, chalybeate, Rockbridge county, Virginia	6.45
Tunbridge Wells, England	7.61
Barέges, France	10.32
Silurian spring, Waukesha, Wis.	18.69
Schlangerbad, Germany	20.46
Aix-les-Bains, France	25.07

KANSAS WATERS.

Conway Springs	3.41	Delaware springs	8.27
Brookville No. 2*	3.84	Parker's	8.89
California	6.13	Linwood*	9.90
Cave spring	6.75	Chico spring	14.92
Brookville No. 1*	8.09	Kansas Clarus	20.83
Sand springs*	8.15		

*Carbon dioxid to form bicarbonates is not included.

Cave Spring, Galena.

Chico Spring, Galena.

Conway Springs.

Delaware Spring.

CHAPTER XIX.

GEOLOGICAL DISTRIBUTION OF MINERAL SPRINGS AND WELLS.

BY W. R. CRANE.

The object of this chapter is to give the formations in which the wells and springs discussed in this report occur, together with a statement regarding the probable source of their waters.

It is often difficult, by simply examining the log of a well, to determine which of a series of water-bearing strata is responsible for the supply.

Wells are often sunk several hundred feet below the stratum which is the main source of supply. Such wells, although cased below the water-bearing strata, may still draw their waters from them. It is, therefore, not uncommon to find wells ranging in depth up into the hundreds of feet which are fed by water-sheets only a hundred feet or so below the surface. Such a condition of affairs is rather confusing when considered from the standpoint of the normal arrangement of a well. Many wells in which the water rises a considerable distance after completion illustrate the condition of affairs stated above, which is, however, frequently attributed to hydraulic waters, or those having to a limited degree the artesian principle.

Distributed throughout the different geological areas, wells have been chosen, which, with generalized sections, are taken to illustrate, as nearly as possible, the geological sequence and association of strata passed through, together with the water-bearing strata, which are, or probably are, the source of waters obtained.

The wells and springs are taken up in the order of the distribution of the geological areas, proceeding from the eastward to

the westward. This arrangement seems the simplest and most logical, as it groups all of the sources of supply into districts, thus facilitating their discussion; otherwise they would be scattered indiscriminately over the whole area of the state, producing a complexity and confusion of arrangement.

The order of the geological areas chosen for this discussion is as follows: Sub-, Lower and Upper Carboniferous, Permian, Red Beds (or Upper Permian), Cretaceous (which may, for convenience in this connection, be divided into the Dakota and the Upper Cretaceous), and lastly the Tertiary.

Discussion of Wells and Springs by Formation.

SUB-CARBONIFEROUS.

Cherokee County. Ball's mineral well is located near the outcrop of the Sub- and Lower Carboniferous strata. It obtains its waters from the Sub-Carboniferous.

Cave and Chico springs, in the neighborhood of Galena, are located in the Sub-Carboniferous strata and draw their waters from the highly fissured limestone and chert formations, which are so productive of lead and zinc in Kansas and Missouri.

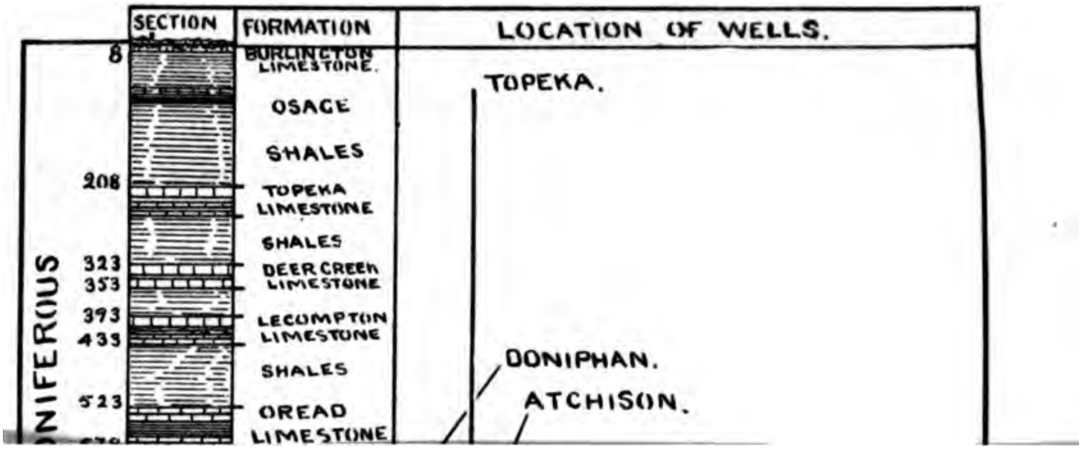
Baxter springs are located just east of the outcrop of the Lower Carboniferous. They have as a source of supply the Sub-Carboniferous.

LOWER CARBONIFEROUS.

Cherokee County. The Columbus well, although situated several miles west of the eastern limit of the Lower Carboniferous, passes through the same and penetrates the Sub-Carboniferous and derives its supply from the same.

Crawford County. The Pittsburg city well was sunk as a prospect hole, but is used at present as a source of water-supply for the city. It passes through the Lower Carboniferous and Sub-Carboniferous and penetrates the Lower Silurian, but probably draws its supply from the Sub-Carboniferous. The Cherokee well also obtains its waters from the Sub-Carboniferous.

The Girard well receives its supply from the lower strata of


SECTION
FORMATION
LOCATION OF WELLS.
8
BURLINGTON LIMESTONE.
OSAGE
SHALES
208
TOPEKA LIMESTONE
SHALES
323
353
DEER CREEK LIMESTONE
393
433
LECOMPTON LIMESTONE
SHALES
523
OREAD LIMESTONE
NIFEROUS
TOPEKA.
DONIPHAN.
ATCHISON.

the Sub-Carboniferous, or from a point near the contact of the Sub-Carboniferous and Lower Silurian.

Bourbon County. The two Bourbon county wells discussed in this report are located at Fort Scott. These wells are known as the artesian and sulfo-magnesian. They both tap the Lower Silurian, from which they draw their waters.

Linn County. The La Cygne iron spring is located in and draws its water from the Lower Carboniferous.

Neosho County. The St. Paul well, although located in the Lower Carboniferous, derives its waters from the Sub-Carboniferous or Lower Silurian, possibly both.

UPPER CARBONIFEROUS.

Labette County. The Mound Valley well probably drains Lower Carboniferous strata.

The Parsons mineral well is situated about on the outcrop of the Upper and Lower Carboniferous strata, but, being shallow, may lie wholly within the Upper Carboniferous.

Montgomery County. The Independence bromo-magnesian well passes through both Upper and Lower Carboniferous and derives its supply from either the Sub-Carbononiferous or Lower Silurian.

The Coffeyville well lies wholly within the Upper Carboniferous strata.

The Coffeyville artesian well taps the Lower Silurian, from which it derives its waters.

The Parkhurst spring has its source in the Upper Carboniferous strata.

Chautauqua County. Chautauqua springs lie within and receive their waters from the Upper Carboniferous.

Wilson County. The Fredonia well extends to the Lower Silurian and probably gets its water from the same.

The Coyville well draws its supply from the Upper or Lower Carboniferous.

The Delaware springs, at Stella, lie wholly within the Upper Carboniferous.

Greenwood County. The Madison sulfur well obtains its waters from the Lower or Sub-Carboniferous.

The Madison salt well has as a source the saliferous shales of the Sub-Carboniferous.

The Eureka mineral well probably lies wholly within the Upper Carboniferous.

Woodson County. The Piqua brine well has as a source of its supply the shales of the Upper and Lower Carboniferous.

The Clarus springs, at Toronto, lie wholly within the Upper Carboniferous.

Allen County. The Iola mineral well probably derives its supply from the Lower Silurian.

Lyon County. Stotler's well draws from the Upper Carboniferous.

Morris County. The Council Grove magnesium well lies within the Upper Carboniferous and probably derives its waters from the same.

Osage County. The Carbondale well lies wholly within the Upper Carboniferous. The Overbrook well also draws from the Upper Carboniferous. The Schoolhouse well is also Upper Carboniferous. The Merrill spring is an Upper Carboniferous product.

Franklin County. Miller's well, at Norwood, probably gets its supply from the Upper Carboniferous.

The Williamsburg well draws its supply from the Upper Carboniferous.

Sylvan springs lie within the Upper Carboniferous.

The California springs are also a product of the Upper Carboniferous.

Douglas County. The Lawrence artesian well draws its supply from either the Sub-Carboniferous or the Lower Silurian, probably the former, or even higher up.

Both Williams and Eudora springs are products of the Upper Carboniferous strata.

Shawnee County. The Boon, Capital and Topeka wells lie within the Upper Carboniferous, which is the source of their supply. Phillips's spring also receives its waters from the Upper Carboniferous strata.

Riley County. The Blasing well, at Manhattan, lies wholly within the Upper Carboniferous.

Leavenworth County. The Kickapoo and Linwood springs both derive their waters from the Upper Carboniferous.

Atchison County. The prospect-hole well, south of Atchison, penetrated the Lower Silurian, but receives its waters both from the Sub- and Lower Carboniferous strata.

The Becker and A. B. C. Laundry wells have, as a source of their waters, the Upper Carboniferous.

The Dixon, McDuff, Arrington and Parker springs obtain their waters from the Upper Carboniferous strata.

Doniphan County. The Eagle springs lie wholly within the Upper Carboniferous strata.

Brown County. The Sun and Sycamore springs both receive their supply from the Upper Carboniferous.

Nemaha County. The Centralia gypsum well draws its supply from the Upper Carboniferous strata, but may be contaminated with the gypsum salts from the Permian strata to the westward.

The Capioma well probably drains Upper Carboniferous strata.

Wyandotte County. The Wyandotte gas well penetrates the Lower Carboniferous strata, from which it receives its supply.

The Forest Lake well is Upper Carboniferous.

Bonner and Forest Lake springs lie wholly within the Upper Carboniferous formation.

PERMIAN.

Sumner County. The Conway spring is situated on the outcrop of the Upper and Lower Permian, or the Red Beds and the Permian strata, receiving its waters largely from the former.

Butler County. The Providence mineral well probably draws its waters from the Upper Carboniferous strata.

Harvey County. The Walton mineral well is Permian.

Marion County. The Marion mineral well probably has its source in the Upper Carboniferous strata.

The Chingawassa springs are all in the Permian.

Dickinson County. The Abilene Gas and Oil Company's well passes into the Lower Carboniferous strata and probably draws its waters from both the Upper and Lower Carboniferous.

The Abilene sand springs are a product of the Permian.

McPherson County. The Conway springs, located on or near the outcrop of the Permian and Tertiary, probably receive their supply from the Tertiary.

Saline County. The Brookville spring lies on or near the outcrop of the Permian and Tertiary and is fed by the Tertiary.

Geary County. The seven springs near Junction City obtain their waters from the Permian.

Clay County. The Wakefield sulfur well lies wholly within the Permian.

Pottawatomie County. Hoover's and Moodyville springs have their source in the Permian strata.

The Louisville iron spring is on or near the outcrop of the Permian and Upper Carboniferous and probably receives most of its waters from the Permian.

Nemaha County. The Neuchatel spring is on or near the outcrop of the Permian and Upper Carboniferous strata. It receives its supply largely from the Permian.

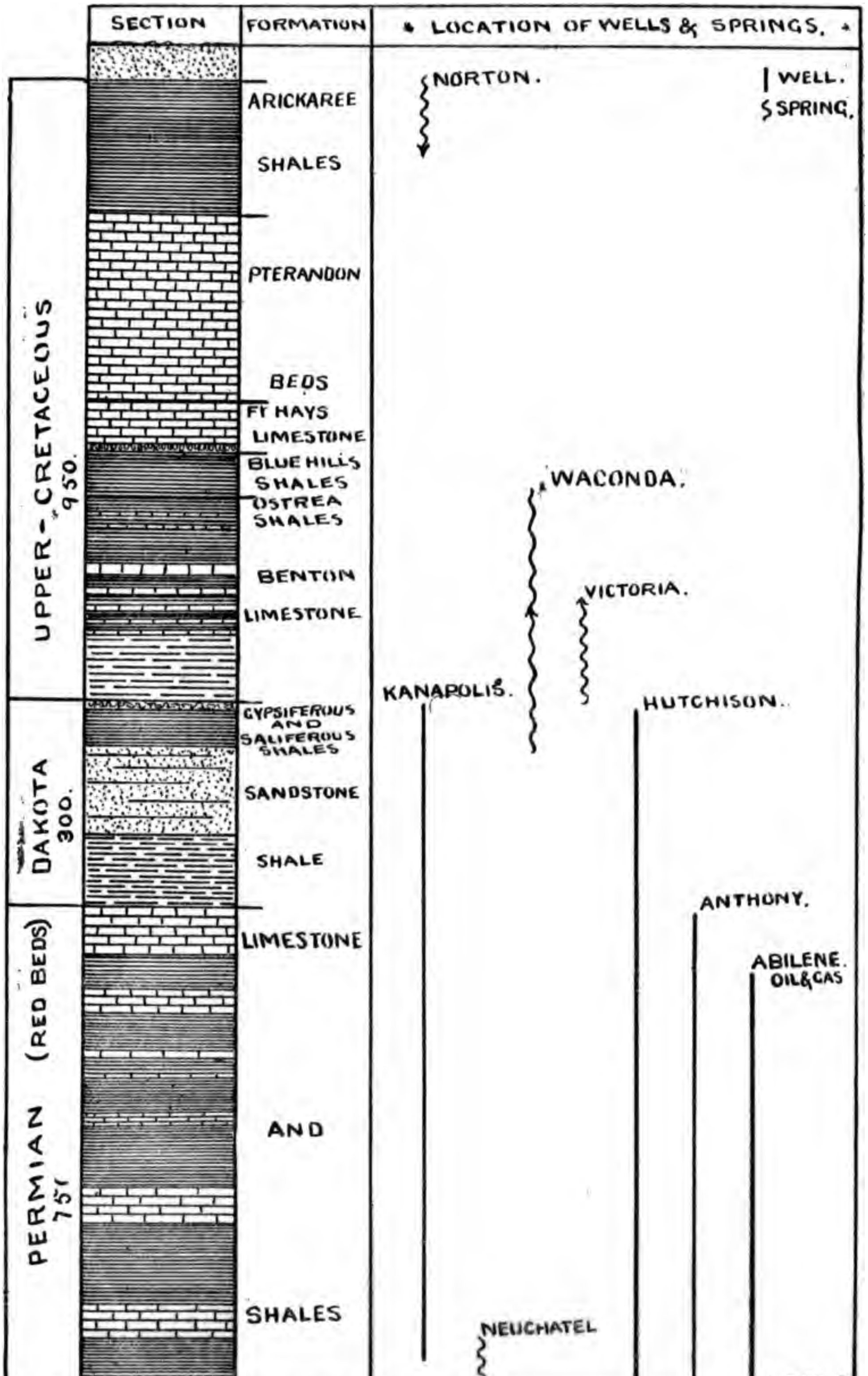
RED BEDS OR UPPER PERMIAN.

The only water that is obtained from this area is that mentioned at Conway, Sumner county.

DAKOTA.

Barton County. The Great Bend mineral well probably receives its supply from the Dakota strata.

Rice County. The Little River mineral spring is on or near



GEOLOGICAL SECTION OF CRETACEOUS, DAKOTA AND PERMIAN FORMATIONS, SHOWING STRATA THAT WOULD BE PIERCED BY WELLS.

the outcrop of the Dakota and Permian. It obtains its waters from the Dakota.

Cloud County. The sulfur spring at Concordia is on or near the outcrop of the Upper Cretaceous and the Dakota and draws its supply largely from the Upper Cretaceous.

TERTIARY.

Cowley County. The Arkansas City mineral well receives its supply from either the Permian or the Upper Carboniferous, probably the former.

The Geuda springs are located on or near the outcrop of the Tertiary and Permian strata, and receive their waters largely from the Tertiary.

Reno County. The Hutchinson brine well, although situated on the Tertiary, draws its supply from the Red Beds or Upper Permian.

UPPER CRETACEOUS.

Mitchell County. The Waconda springs are, in some respects, the most interesting natural phenomena known in the state. They are what might be called deep-seated springs, as they draw their supply through a considerable vertical distance from the saliferous shales overlying the Dakota.

Ellis County. The Victoria spring exists in the Upper Cretaceous and obtains its waters from the same.

Russell County. The spring at Fay lies wholly within the Upper Cretaceous.

Jewell County. White Rock and Omio springs receive their waters from the Upper Cretaceous.

The Burr Oak well also drains the Upper Cretaceous strata.

As previously stated, it is a rather difficult task to give anything like an exact geological position to the sources of supply of wells and springs, especially wells, as the depth is, in most cases, not exactly known, and, even if it were, an element of doubt exists.

Springs are usually merely superficial phenomena, while wells, as a rule, especially mineral wells, extend to and often through several unaltered formations, thus drawing their supply from the vadose or deeper-seated superficial waters.

From the depth of many of the wells discussed in this report, it is evident that they are receiving their waters from surface accumulation's of eroded and disintegrated formations. They cannot, therefore, be said to exist in any geological formation, but have been located geographically by geological areas.

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